



# Registration and processing of biosignals and medical images

## Working program of basic discipline (Silabus)

### Requisites for basic discipline

Level of higher education	<i>First (bachelor's)</i>
Branch of knowledge	<i>16 Chemical and Bioengineering</i>
Specialty	<i>163 Biomedical Engineering</i>
Educational program	<i>Medical Engineering</i>
Discipline status	<i>Elective discipline</i>
Form of study	<i>full-time / day / mixed / remote</i>
Year of preparation, semester	<i>3rd course, autumn semester</i>
The scope of discipline	<i>4 ECTS credits / 120 hours</i>
Semester control / Control measures	<i>Test Work, Modular Test Work, Review</i>
Lessons schedule	<i>According to the schedule on the site <a href="http://rozklad.kpi.ua/">http://rozklad.kpi.ua/</a></i>
Language of instruction	<i>English</i>
Information about course leader / teachers	<i><b>Lecturer:</b> Candidate of Technical Sciences, Associate Professor Anton Popov, e-mail: <a href="mailto:popov-ee@ill.kpi.ua">popov-ee@ill.kpi.ua</a>, Telegram: <a href="https://t.me/antpantp">https://t.me/antpantp</a> <b>Practical:</b> Candidate of Technical Sciences, Associate Professor Kateryna Ivanko Popov, e-mail: <a href="mailto:ivanko-ee@ill.kpi.ua">ivanko-ee@ill.kpi.ua</a> Candidate of Technical Sciences, Associate Professor Anna Poreva, e-mail: <a href="mailto:porevanna-ee@ill.kpi.ua">porevanna-ee@ill.kpi.ua</a></i>
Course placement	<i>Platform «Sikorsky» - course «Registration and processing of biosignals and medical images»</i>

### Distribution of hours

Semester	Lectures	Practical	Laboratory	Independent Work
<i>autumn semester</i>	<i>26</i>	<i>28</i>	<i>18</i>	<i>48</i>

### Curriculum of the discipline

#### 1. Description of the discipline, its purpose, subject of study and learning outcomes

*The main purpose of the discipline "Registration and processing of biosignals and medical images" (RPBMI) is to form a holistic view of signals and methods of their study, as well as the acquisition of knowledge, skills, abilities and experience in using methods of processing and analysis of biosignals and images in practice. It studies mathematical methods of analysis of biomedical signals and images and systems of their processing.*

*Learning in the discipline is carried out on the basis of student-centered approach and strategy of interaction between teacher and student in order for students to master the material and develop their practical skills.*

Skills are required to study the discipline:

1. Programming skills (Python).
2. Mathematics (basic course of functions, series, Fourier integral).

**General competencies** (OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):

**GC 1** - Ability to apply knowledge in practical situations.

**GC 5** - Ability to perform research at the appropriate level.

**Special (professional) competencies** (OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):

**PC 1** - Ability to use engineering software packages for research, analysis, processing and presentation of results, as well as for automated design of medical devices and systems.

**PC 14** - Ability to perfect experiments according to specified technical and medical methods, perform computer processing, analysis and synthesis of the results.

**The program learning outcomes after studying the discipline "Microprocessor Engineering" are** (OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):

**PLO 4** - Knowledge of methods of designing digital and microprocessor systems for medical purposes.

**PLO 16** - Application of modern programming technologies and tools that support their use.

**PLO 31** - Understanding of theoretical and practical approaches to the creation and management of medical equipment and medical technic.

## **2. Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)**

The discipline is interdisciplinary. It integrates knowledge from other disciplines according to its subject. According to the structural and logical scheme of the training program, the discipline is closely related to other disciplines of general and professional training: "Mathematical analysis" (in sections related to integration, operational calculus and series theory), "Analytical geometry" (in sections related to the representation of vectors in Euclidean spaces), "Algorithmization and programming" (in sections related to the basics of algorithms and programming).

The acquired practical skills and acquired theoretical knowledge during the study of the discipline can be used in the future during the acquisition of disciplines:

- from the cycle of professional training (educational-professional program "Medical Engineering"): "Biomedical devices, apparatus and complexes";
- from elective disciplines (educational-professional program "Medical Engineering"): "Medical equipment", "Development and operation of physiotherapeutic medical devices", "Medical-diagnostic complexes based on biophotonic converters", "Design of medical information systems";
- "System analysis", "Data mining", "Fundamentals of artificial intelligence" and disciplines of the training program at the educational and MSc qualification level.

## **3. The content of the discipline**

The main sections and topics that will be considered in the process of studying the course:

### **Section 1. Introduction to signal registration and analysis.**

Subject 1.1. Biomedical electronic systems.

Subject 1.2. Types and characteristics of biosignals and medical images.

Subject 1.3. Registration of biosignals and medical images.

## **Section 2. Digital medical systems.**

Subject 2.1. Linear time-invariant digital systems.

Subject 2.2. Description of LTI digital systems.

## **Section 3. Signal decomposition in Hilbert space.**

Subject 3.1. Main terms and definitions.

Subject 3.2. Generalized Fourier series.

## **Section 4. Fourier analysis.**

Subject 4.1. Continuous signals.

Subject 4.2. Discrete signals.

Subject 4.3. Time-frequency decomposition.

Subject 4.4. Walsh-Hadamard and wavelet transforms.

## **Section 5. Digital filters.**

Subject 5.1. Digital filtration basics.

Subject 5.2. Digital filter design.

## **Section 6. Digital image analysis.**

Subject 6.1. Spatial processing.

Subject 6.2. Frequency-domain processing.

## **Section 7. Nonlinear signal analysis.**

Subject 7.1. Univariate methods.

Subject 7.2. Multivariate methods.

## **Section 8. Basics of machine learning.**

Subject 8.1. Feature engineering.

Subject 8.2. Machine learning.

## **4. Training materials and resources**

### **Basic literature:**

1. Теорія сигналів: Лабораторний практикум. [Електронний ресурс] : навч. посіб. для здобувачів ступеня бакалавра за спеціальністю 153 «Мікро- та наносистемна техніка» / КПІ ім. Ігоря Сікорського ; уклад.: А.О. Попов, А.С. Порєва, К.О. Іванько. – Київ : КПІ ім. Ігоря Сікорського, 2019. – 54 с.
2. Теорія сигналів: Практикум [Електронний ресурс] : навч. посіб. для здобувачів ступеня бакалавра за освітньою програмою "Електронні мікро- і наносистеми та технології" спеціальності 153 "Мікро та наносистемна техніка" / КПІ ім. Ігоря Сікорського ; уклад.: А.О. Попов, А.С. Порєва, К.О. Іванько, І.П. Голубєва, Є.С. Карплюк. – Електронні текстові дані (1 файл: 1909 Кбайт). – Київ : КПІ ім. Ігоря Сікорського, 2020. – 65 с.
3. Теорія сигналів [Електронний ресурс] : навч. посіб. для здобувачів ступеня бакалавра за спеціальністю 153 «Мікро- та наносистемна техніка» / КПІ ім. Ігоря Сікорського ; уклад.: А.О. Попов. – Електронні текстові дані (1 файл: 7399 Кбайт). – Київ : КПІ ім. Ігоря Сікорського, 2019. – 268 с.

### **Additional literature:**

1. Френкс Л. Теория сигналов. – М.: Сов. радио, 1974. – 344 с.
2. Оппенгейм А.В., Шафер Р.В. Цифровая обработка сигналов. – М.: Связь, 1979. – 416 с.
3. Марпл-мл. С.Л. Цифровой спектральный анализ и его приложения: Пер. с англ. М.: Мир, 1990. 548 с.
4. Лайонс Р. Цифровая обработка сигналов. – М.: ООО «Бином-пресс», 2006. – 656 с.

5. Айфичер Э.С., Джервис Б.У. Цифровая обработка сигналов: практический подход. – М.: Издательский дом «Вильямс», 2004. – 992 с.

6. Bronzino J. D. *The biomedical engineering handbook*. Boca Raton: CRC Press LLC, 2000.

## Educational content

### 5. Methods of mastering the discipline (educational component)

№ з/п	Тема	Програмні результати навчання	Основні завдання	
			Контрольний захід	Термін виконання
1.	<i>Introduction to signal registration and analysis</i>	PLO 4, 16	<i>Modular Test Work -1</i>	8 <sup>th</sup> week
2.	<i>Digital medical systems</i>	PLO 4, 16	<i>Modular Test Work -1</i>	8 <sup>th</sup> week
3.	<i>Signal decomposition in Hilbert space</i>	PLO 16	<i>Modular Test Work - 1</i>	14 <sup>th</sup> week
4.	<i>Fourier analysis</i>	PLO 16	<i>Modular Test Work - 2</i>	14 <sup>th</sup> week
5.	<i>Digital filters</i>	PLO 16	<i>Modular Test Work - 2</i>	14 <sup>th</sup> week
6.	<i>Digital image analysis</i>	PLO 4, 31	Test	Session
7.	<i>Nonlinear signal analysis</i>	PLO 4, 31	Test	Session
8.	<i>Basics of machine learning</i>	PLO 4, 31	Test	Session

### 6. Independent student work

One of the main types of semester control during the mastering of the discipline is the implementation of review.

The main purpose of review is the study of the current state of the art in the domain of digital analysis of medical signals and images. The subject is "Theory and applications of processing and analysis of medical signals and images".

The title page of the Review should have the following content: the name of the university; name of the faculty; name of department; name of specialty, name of educational-professional program, name of academic discipline; topic of the abstract; surname and name of the student, course, number of the academic group, year.

The title page is followed by a detailed plan (content) of the Review, which should highlight the introduction, sections of the main content (main topics studied), their subdivisions (if necessary), conclusion, list of sources used. The table of contents on the right indicates the page numbers at the beginning of each question. Each section begins on a new page.

The total volume of the Review work, depending on the chosen topic, can vary from 10 to 15 pages of the main text (in agreement with the teacher). The volume of the abstract is determined by the student's ability to concisely and at the same time comprehensively reveal the chosen topic.

Mandatory requirement: clear reference to sources of information. All figures, facts, opinions of scientists, quotations, formulas must have a reference in the form [2, p. 54] (the first digit means the number of the source in the list of references given at the end of the creative work, and the second digit -

the page number in this source). It is desirable to use tables, diagrams, graphs, charts, etc. The list of used sources (not less than 5 sources) is made out according to operating rules. If the information is taken from the Internet, you need, as for ordinary literature, to indicate the author, the title of the article, and then provide the address of the site on the Internet.

The Review work is evaluated by the following criteria: logic of the plan; completeness and depth of disclosure of the topic; reliability of the received data; display of practical materials; correct formulation of conclusions and conclusions; design; substantiation of the student's own opinion on this issue in the form of a conclusion.

Deadline for submission of Review work for review: 13th week of study.

The Review work is not tested for plagiarism, but must meet the requirements of academic integrity. In case of academic dishonesty, the work is canceled and not checked.

## Policy and control

### 7. Policy of academic discipline (educational component)

#### Attending classes

Attendance at lectures is optional. Attending practical classes is desirable, as they are used to write express tests / tests, as well as to defend practical work.

The grading system is focused on obtaining points for student activity, as well as performing tasks that are able to develop practical skills and abilities.

#### Control measures missed

Missed control measures (defense of laboratory work) must be practiced in the next classes, provided that the task is scheduled for the current lesson, or in consultations.

Omissions of writing a module test and express test are not fulfilled.

Review which is submitted for inspection in violation of the deadline is evaluated with a decrease in the number of weight points.

#### Violation of deadlines and incentive points

Encouragement points		Penalty points *	
Criterion	Weight points	Criterion	Weight points
Passing distance courses on topics that are agreed with teachers	20 points	Certificate	1
Registration of scientific work for participation in the competition of student scientific works	20 points	Submission of the work	1
Writing abstracts, articles, participation in international, national and / or other events or competitions on the subject of the discipline	20 points	Submission of the work	1

\* if the control measure was missed for a good reason (illness, which is confirmed by a certificate of the established sample) - penalty points are not accrued.

#### Academic integrity

The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more: <https://kpi.ua/code>.

#### Norms of ethical behavior

Normative principles of behavior of students and employees, defined in sections 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more: <https://kpi.ua/code>.

### **Procedure for appealing the results of control measures**

Students have the opportunity to raise any issue related to the control procedure and expect it to be addressed according to predefined procedures.

The student has the right to appeal the results of the control measure according to the approved provision on appeals in the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (approved by the order №NON/128/2021 from 20.05.2021) - <https://osvita.kpi.ua/index.php/node/182>

### **Inclusive education**

The discipline "Automated Design Systems" can be taught to most students with special educational needs, except for students with severe visual impairments who do not allow to perform tasks using personal computers, laptops and / or other technical means.

### **Distance learning**

Distance learning takes place through the Sikorsky Distance learning Platform «Sikorsky».

Distance learning through additional online courses on certain topics is allowed subject to agreement with students. If a small number of students wish to take an online course on a specific topic, studying the material with such courses is allowed, but students must complete all the tasks provided in the discipline.

The list of courses is offered by the teacher after the students have expressed a desire (because the bank of available courses is updated almost every month).

The student provides a document confirming the completion of the distance course (in the case of a full course) or provides practical tasks from the distance course and subject to an oral interview with the teacher on the topics can receive grades for control measures provided for the studied topics (express control / test tasks, practical work).

Performance of practical works, and also performance of settlement and graphic work, is carried out during independent work of students in a remote mode (with a possibility of consultation with the teacher through e-mail, social networks).

### **Learning a foreign language**

Teaching in English is carried out only for foreign students.

At the request of students, it is allowed to study the material with the help of English-language online courses on topics that correspond to the topics of specific classes.

## **8. Monitor and evaluate the system of evaluation of learning outcomes (Rating System of Evaluation)**

### **Evaluation system (current control):**

No s/n	Control measure	%	Weight points	Number	Total
1.	Laboratory work #1	14	20	1	20
2.	Laboratory works #2-5	24	5	4	20
4.	Modular control work (MCW)	15	15	2	30
5.	Review work (RW)	20	30	1	30



No s/n	Control measure	%	Weight points	Number	Total
6.	Test work <sup>1</sup>	100	100	1	100
	Total				100

The applicant receives a positive credit score for the results of the semester, if he has a final rating for the semester of at least 60 points and has met the conditions of admission to the semester control, which are determined by the RSE (Rating System of Evaluation).

With applicants who have met all the conditions of admission to the test and have a rating of less than 60 points, as well as with those applicants who want to increase their rating, in the last scheduled lesson in the semester, the teacher conducts semester control in the form of test or interviews.

After performing the test, if the score for the test is higher than the rating, the applicant receives a score based on the results of the test.

If the grade for the test is lower than the rating, a "hard" RSE is used - the previous rating of the applicant (except for points for the semester individual task) is canceled and he receives a grade based on the results of the test. This option forms a responsible attitude of the applicant to the decision to perform the test, forces him to critically assess the level of his training and carefully prepare for the test.

**Calendar control (CC)** - is performed twice a semester as monitoring of the current state of compliance with syllabus requirements.

The purpose of calendar control is to improve the quality of student learning and monitor the implementation of the schedule of the educational process by students.

Criterion		The first CC	The second CC
Deadline of calendar controls		8th week	14th week
Conditions for obtaining a positive result from the calendar control	Current rating		≥ 50% points
	Execution of laboratory works	LW № 1-3	+
		LW № 4-5	-
	Modular control work	MCW	+
Review work	RW	-	

In case of detection of academic poor quality during training - the control measure is not credited.

### Semester certification of students

Mandatory condition for admission to the test		Criterion
1	Current rating	RD ≥ 50
2	Obtaining a positive assessment for the performed Review	≥ 0

The results are announced to each student separately in the presence or remotely (by e-mail). Also recorded in the system "Electronic Campus".

Optional conditions for admission to closure:

1. Activity in practical classes.
2. Activity in laboratory classes.

<sup>1</sup> Враховується в суму рейтингу разом з оцінкою за РГР у разі, якщо студент не набрав 60 балів за семестр або він хоче покращити свою оцінку.

3. *Positive result of the first attestation and the second attestation.*

*Table of translation of rating points to grades on a university scale:*

<i>Number points</i>	<i>Assessment on the university scale</i>
<i>100-95</i>	<i>Perfectly / Відмінно</i>
<i>94-85</i>	<i>Very good / Дуже добре</i>
<i>84-75</i>	<i>Good / Добре</i>
<i>74-65</i>	<i>Satisfactorily / Задовільно</i>
<i>64-60</i>	<i>Enough / Достатньо</i>
<i>Less 60</i>	<i>Unsatisfactorily / Незадовільно</i>
<i>Admission conditions are not met</i>	<i>Not allowed / Не допущено</i>

**9. Additional information on the discipline (educational component)**

*The list of questions for preparation for modular control work, and also for preparation for credit is given in appendix 1.*

*Distance learning through additional online courses on certain topics is allowed subject to agreement with students. If a small number of students wish to take an online course on a specific topic, studying the material with such courses is allowed, but students must complete all the tasks provided in the discipline.*

*The list of courses is offered by the teacher after the students have expressed a desire (because the bank of available courses is updated almost every month).*

*The student provides a document confirming the completion of the distance course (in the case of a full course) or provides practical tasks from the distance course and subject to an oral interview with the teacher on the topics can receive grades for control measures provided for the studied topics (express control / test tasks, practical work).*

**Work program of the discipline (syllabus):**

**Compiled by** Associate Professor, Candidate of Technical Sciences, Anton Popov.

**Approved by** the Department of Biomedical Engineering (protocol № \_\_\_ to \_\_\_\_\_)

**Approved by** the Methodical Commission of the Faculty of Biomedical Engineering (protocol № \_\_ to \_\_\_\_\_)



***The list of questions for preparation for modular control work,  
And also for preparation for test***

- 1. Biomedical electronic systems.*
- 2. Types and characteristics of biosignals and medical images.*
- 3. Registration of biosignals and medical images.*
- 4. Linear time-invariant digital systems.*
- 5. Description of LTI digital systems.*
- 6. Main terms and definitions of signal decomposition.*
- 7. Generalized Fourier series.*
- 8. Fourier analysis of continuous signals.*
- 9. Fourier analysis of discrete signals.*
- 10. Time-frequency decomposition.*
- 11. Walsh-Hadamard transform*
- 12. Wavelet transform.*
- 13. Digital filtration basics.*
- 14. Digital filter design.*
- 15. Spatial image processing.*
- 16. Frequency-domain image processing.*
- 17. Univariate methods of signal analysis.*
- 18. Multivariate methods of signal analysis.*
- 19. Feature engineering basics.*
- 20. Machine learning basics.*