National Technical University of Ukraine“ Igor Sikorsky Kyiv Polytechnic Institute”

Department of Biomedical Engineering

Electronic sensors and biochips

Working program of basic discipline (Syllabus)

Requisites for basic discipline	
Level of higher education	*Second (master's)*
Branch of knowledge	*16 Chemical and Bioengineering*
Specialty	*163 Biomedical Engineering*
Educational program	*Medical Engineering*
Discipline status	*Discipline of choice*
Form of study	*full-time / day / mixed / remote*
Year of preparation, semester	*1 course (spring semester)*
The scope of discipline	*5 ECTS credits / 150 hours*
Semester control / Control measures	*Modular Test Work, Calculation and Graphic Work, Exam*
Lessons schedule	*According to the schedule on the site http://rozklad.kpi.ua/*
Language of instruction	*English*
Information about course leader / teachers	***Lecturer:*** *Candidate of Technical Sciences, Associate Professor, Head Department of ME Anatolii T. ORLOV , e-mail: a.orlov@kpi.ua, Telegram: @Anatolii_Orlov, m. 0679825255*[1] ***Practical:*** *Candidate of Technical Sciences, Associate Professor, Head Department of ME Anatolii T. ORLOV , e-mail: a.orlov@kpi.ua, Telegram: @Anatolii_Orlov, m. 0679825255*[2]
Course placement	*Platform «Sikorsky» - course « Electronic sensors and biochips» (GoogleClass link)*

Distribution of hours

Semester	Lectures	Practical	Laboratory	Independent Work
spring semester	*28*	*26*	*18*	*78*

Curriculum of the discipline

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

The discipline "Electronic sensors and biochips" (hereinafter ESBC) is very important for the study of future masters of biomedical engineering, because modern methods and equipment for diagnosing diseases, monitoring the physical condition of people in clinics, outpatient clinics and training institutions, in biomedical research using a huge number of electronic sensors. The discipline of ESBC is selective and provides an opportunity to form an individual educational trajectory, including the individual choice of academic disciplines in the amount provided by the legislation of Ukraine on higher education

The purpose of studying the discipline are:

- provide justification for the mechanisms of conversion of certain physical, chemical and biomedical quantities (temperature, pressure, concentration, displacement, velocity, acceleration, pH, etc.) into an electrical signal used to build sensors and biochips;

- gaining knowledge for independent development on the basis of the studied physical and other effects of new types of biomedical sensors and devices and equipment with their use.

After mastering the discipline, students must demonstrate the following learning outcomes:

knowledge: basic indicators of human physical condition and the theory of obtaining biosignals, physical phenomena (effects), which underlie the operation of modern sensors of temperature, pressure, gas, humidity, physiological fluids, displacement, velocity, acceleration, magnetic fields and radioactivity, etc.

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

1. *GC 1 - Ability to abstract thinking, analysis and synthesis.*
2. *GC 2 - Ability to search process and analyze information from various sources.*
3. *GC 3 - Ability to identify, pose and solve problems.*
4. *GC 5 - Ability to work in an international context.*

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

1. *GC 1 - Ability to solve complex problems of biomedical engineering using methods of mathematics, natural and engineering sciences.*
2. *GC 2 - Ability to develop a working hypothesis, plan and set experiments to test the hypothesis and achieve the engineering goal with the help of appropriate technologies, technical means and tools.*
3. *GC 3 - Ability to analyze complex medical and bioengineering problems and formalize them to find quantitative solutions using modern mathematical methods and information technology.*
4. *GC 4 - Ability to create and improve tools, methods and technologies of biomedical engineering for research and development of bioengineering facilities and systems for medical and technical purposes.*
5. *GC 5 - Ability to develop technical tasks for the creation, as well as model, evaluate, design and construct complex bioengineering and medical engineering systems and technologies.*
6. *GC 8 - Ability to develop models and conduct experiments aimed at solving problems related to human health, according to the specific needs of scientific research, analyze, explain the results and evaluate the cost of research.*
7. *GC 9 Ability to create tools and methodologies of scientific activity, evaluation and implementation of the results of modern developments, solutions and achievements of engineering and exact sciences in medicine and biology.*
8. *GC 12 - Ability to conduct research and observations on the interaction of biological, natural and artificial systems (prostheses, artificial organs, etc.), to plan biotechnical tests of artificial prostheses and systems.*

Learning outcomes after studying the discipline (Practical Skills):

1. *PSK 1 Understanding of fundamental-applied, medical-physical and bioengineering bases of technologies and equipment for research of physiological and pathological processes of the person.*
2. *PSK 2 Understanding the principles of operation of modern diagnostic equipment and systems for displaying biomedical information, the basics of relevant software.*
3. *PSK 4 Application of methods of calculation and selection of classical and new designs of biomaterials, elements of devices and systems of medical appointment.*
4. *PSK 7 Possession of methods of research, design and construction of biomedical equipment, analysis and processing of experimental data.*
5. *PSK 8 Knowledge of general requirements for the conditions of engineering, technological and scientific projects.*
6. *PSK 9 Knowledge of the principles of development and modern problems of creating biocompatible*

materials in medical practice.
7. PSK 13 Knowledge of a foreign language to the extent sufficient for general and professional communication
8. PSK 16 Knowledge of methods of design, construction, improvement and application of medical and technical and bioengineering products, devices, devices and systems in compliance with technical requirements, as well as to support their operation.
9. PSK 25 Implementation of achievements of domestic and foreign science and technology, use of creative initiative, rationalization, invention and best practices that ensure the effective operation of the medical enterprise.

Program learning outcomes, control measures and deadlines are announced to students in the first lesson.

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

The discipline ESBC is interdisciplinary. It integrates according to its subject knowledge from other educational and scientific fields: physiology, biochemistry, biophysics, mechanics, materials science, electronics, laboratory, medical and diagnostic medical equipment, obtaining and processing signals and images. According to the structural and logical scheme of the master's program in biomedical engineering is related to other disciplines, modern research in the specialty and technology in health care.

Prerequisites: *Physics; Theory of biomedical signals; Analog circuitry; Electrical engineering and electronic devices-1; Biophysical converters; Biomedical devices, apparatus and complexes-1; Diagnostic technique.*

Postrequisites: *Master's thesis in the field of biomedical engineering.*

3. The content of the discipline

List of sections and topics:

Section 1. Sensory measurements.

Topic 1.1 Classification of sensors. Active and passive sensors.

Topic 1.2 Measurements in biomedicine.

Topic 1.3 Devices for processing measuring signals.

Topic 1.4 Schemes of signal formation of passive sensors.

Topic 1.5 Schemes of inclusion of active sensors.

Section 2. Features of designing biomedical sensors.

Topic 2.1 Biophysical signals. Measurement object activity and individual feature.

Topic 2.2 Models and designs of biomedical electrodes. Areas of application of biomedical sensors.

Section 3. Optoelectronic and fiber-optic sensors.

Topic 3.1 Classification of fiber-optic sensors.

Topic 3.2 Modern optoelectronic sensors. Features of pulse oximetry.

Section 4. Temperature sensors.

Topic 4.1 Resistance thermometers.

Topic 4.2 Thermocouple sensors.

Topic 4.3 Temperature sensors on the photo effect.

Topic 4.4 Dielectric temperature sensors.

Topic 4.5 Temperature sensors on semiconductor structures.

Section 5. Mechanical and acoustic sensors.

Topic 5.1 Acoustic research in medicine.

Topic 5.2 Registration of static and dynamic mechanical stresses.

Topic 5.3 Tensor-resistant transducers, the use of silicon to measure deformation. Piezoelectric OAH and PAH sensors.

Topic 5.4 Accelerometers. Flow sensors. Linear and angular velocity sensors.

Topic 5.5 Pressure sensors and their use in biomedicine. MEMS technologies and sensors.

Section 6. Magnetic field sensors.

Topic 6.1 Interaction of a magnetic field with a solid body. Hall effect. Magnetic resistors.

Topic 6.2 Interaction of the magnetic field with biological objects.

Topic 6.3 Influence of magnetic fields on the parameters of semiconductor devices.

Section 7. Rigid radiation sensors.

Topic 7.1 Detectors based on gas ionization.

Topic 7.2 Semiconductor detectors.

Topic 7.3 Scintillation detectors.

Section 8. Gas sensors.

Topic 8.1 Sorption sensors QCM sensors. Humidity sensors.

Topic 8.2 Calorimetric and catalytic methods for determining the gas composition.

Topic 8.3 Optical and ultrasonic methods for determining the composition of gas.

Topic 8.4 Ion-selective field-effect transistors and MDN varactors.

Section 9. Sensors of physiological fluids.

Topic 9.1 Electrochemical methods for the study of liquids.

Topic 9.2 Amperometric, potentiometric and conductometric sensors.

Topic 9.3 Glucose, sweat, tear fluid and urea sensors. Biochemical and immune sensors.

Section 10. Biosensors and biochips.

Topic 10.1 Folded sensors. The structure of biosensors. Biomedical nanosensors.

Topic 10.2 DNA-based sensors.

Topic 10.3 Principles of construction of biochips. Electronic interfaces with biomedical facilities.

Topic 10.4 Multiparametric sensors "electronic nose" and "electronic language".

***Modular control test** is a current control measure, which includes practical skills to apply modern tools and technologies of search, processing and analysis of information, research related to biomedical sensory interdisciplinary areas using modern tools; critically analyze the results of their own research and the results of other researchers. Performed and handed over individually in different sections of the discipline.*

Modular control work is an ongoing control measure that covers practical skills in the application of biomedical sensors. The list of questions on which tickets for modular control work are formed: 1. Basic concepts and classification of sensors. 2. The effect of temperature on the electrical conductivity of metals. 3. The effect of temperature on the electrical conductivity of alloys. 4. Metal resistance thermometers. 5. Influence of temperature on electrical conductivity of semiconductors. 6. Semiconductor resistance thermometers. 7. Mattisen's rule. Nordheim's law. 8. Wire and film metal thermistors. 9. Thermistors and posistors 10. The physical essence of the Seebeck effect in metals 11. The physical essence of the Seebeck effect in semiconductors. 12. Metal thermocouple thermometers. 13. Comparison of thermoresistive and thermocouple sensors 14. The influence of the nature of the material on the characteristics of photodetectors of infrared radiation. 15. Thermal and photonic IR receivers. Definition and comparison. 16. Radiation of a heated body. Basic laws of absorption and radiation. 17. The structure of thermal converters. 18. Temperature indicators. 19. Thermal sensors 20. Features of photonic IR receivers 21. Features of thermal IR receivers 22. Ferroelectrics and their applications. 23.

Capacitive temperature sensors based on ferroelectrics 24. The physical essence of the pyroelectric effect and its application. 25. Pyroelectric temperature sensors. 26. Thermodiodes and thermotransistors The list of questions on which tickets for control work are formed №2: 27. Creation and registration of elastic oscillations. Sound and sound waves. 28. Scheme of acoustic measuring path 29. Types of electroacoustic transducers 30. Direct and reverse piezoelectric effects 31. Requirements for materials for observing the piezoelectric effect. Piezo materials. 32. Application of acoustic research in medicine 33. Ultrasound diagnostics 34. Mechanical stresses and methods of their registration. 35. Tensometry and its areas of application. 36. Tensor resistance effect in metals and alloys 37. Design varieties of strain gages 38. Tensor resistance effect in semiconductors and semiconductor devices 39. Gas analyzers and hygrometers. Basic concepts, classification and areas of application. 40. Mechanisms of sorption of gases on the surface of a solid body. 41. Varieties of sorption processes. Adsorption and absorption. Physical and chemical adsorption. 42. Gravimetric method for determining gas sorption. 43. Resistive and capacitive moisture sensors. 44. Influence of gas sorption on electro-physical properties of semiconductors. 45. Chemisorption of gas on a p-type semiconductor. 46. Chemisorption of gas on an n-type semiconductor. 47. Adsorption centers on the surface of a solid. 48. Semiconductor gas analyzers. 49. Resistive gas sensors. 50. Gas sensors based on MDN structures, Schottky barrier and heterojunctions 51. Optical methods for determining the composition of gas 52. Thermal methods for determining the composition of gas 53. Calorimetric methods for determining the composition of gas 54. Catalytic gas sensors 55. Refractometric method of gas analysis.

4. Training materials and resources

Basic literature:

1. Harsanyi, G. (2000). Sensors in Biomedical Applications: Fundamentals, Technology and Applications (1st ed.). CRC Press. 368 p.

2. Електронні методи і засоби біомедичних вимірювань. Навчальний посібник Рекомендовано Вченою радою НТУУ «КПІ» (протокол № 6 від16. 05. 2016 р) /С.К. Мещанінов, В. М. Співак, А. Т. Орлов. – К.: Кафедра, 2016. – 211 с. (ISBN 978-617-7301-18-8)

3. Мікроелектронні сенсори фізичних величин: В 3-ох т. / В. Вуйцік, З. Готра, О. Готра та інш.; Львів: Ліга-Прес, 2003. – 595 с.

4. Дзядевич С.В., Солдаткін О.П. Наукові та технологічні засади створення мініатюрних електрохімічних біосенсорів.- Київ: Наукова думка. 2006.-255с.

5. Дзядевич С. В. Амперометричні ферментні біосенсори / С. В. Дзядевич // Biotechnologia Acta . - 2008. - Т. 1, № 1. - С. 46-60. - Режим доступу: http://nbuv.gov.ua/j-pdf/biot_2008_1_1_7.pdf

6. Эггинс Б. Химические и биологические сенсоры. - М.: Техносфера, 2005,-336с.

7. Биосенсоры: Основы и приложения. /Под ред. Э.Тернера и др.-М.: Мир. 1992.-614с.

8. Биосенсоры/Под ред. А.М.Егорова.- М.: Наука, 1990.-164с.

Additional literature:

1. Засоби та методи вимірювань неелектричних величин: підручник / Є.С. Поліщук [та ін.] Львів: Вид-во "Бескид Біт", 2008. – 618 с.

2. Фрайден Дж. Современные датчики. Справочник.- М.: Техносфера, 2005.-588с.

3. *Бусурин В.И., Носов Ю.Р., Волоконно-оптические датчики. Физические основы, вопросы расчета и применения. -М.: Энергоатомиздат, 1990.-320с.

4. Датчики измерительных систем: В 2-х кн.: пер. с франц. / Ж. Аш и др. М.: Мир, 1992. – 480 с.

5. Датчики. Устройство и применение: пер. с нем. / Г. Виглеб. М.: Мир, 1989. – 196с.

6. Джексон Р. Г. Новейшие датчики. – М.: Техносфера, 2007. – 384 с.

Educational content

5. Methods of mastering the discipline (educational component)

№ s/n	Subject	Program learning outcomes	The main tasks	
			Control measure	Deadline
Section 1. Sensory measurements				
1	*Introduction. Terms and definitions. Errors. Classification of sensors. Active and passive sensors. Measurements in biomedicine. Measuring signal processing devices.*	*PLO 5 PLO 7 PLO 9*	*Practical work 1*	*1st week*
2	*Schemes of signal formation of passive sensors. Schemes of inclusion of active sensors.*	*PLO 7 PLO 9*	*Practical work 2*	*2nd week*
Section №2 Features of designing biomedical sensors				
3	*Biophysical signals. Measurement object activity and individual feature. Models and designs of biomedical electrodes. Areas of application of biomedical sensors.*	*PLO 5 PLO 8*	*Practical work 3, Laboratory work 1*	*3rd week*
Section №3 Optoelectronic and fiber-optic sensors				
4	*Classification of fiber-optic sensors. Modern optoelectronic sensors. Features of pulse oximetry.*	*PLO 8 PLO 10 PLO 19*	*Practical work 4 Laboratory work 2*	*4th week*
Section № 4 Temperature sensors				
5	*Thermoresistors. Thermocouple sensors. Temperature sensors on the photo effect. Dielectric temperature sensors. Temperature sensors based on semiconductor structures.*	*PLO 8 PLO 12*	*Practical work 5 Laboratory work 3*	*5th week*
Section № 5 Mechanical and acoustic sensors				
6	*Acoustic research in medicine. Piezoelectric BAW and SAW sensors.*	*PLO 4 PLO 9*	*Practical work 6*	*6th week*

7	*Registration of static and dynamic mechanical stresses. Tensor-resistant transducers, use of silicon to measure deformation.*	*PLO 9* *PLO 11*	*Practical work 7* *Laboratory work 4*	*7th week*
8	*Accelerometers. Flowmeter sensors. Linear and angular velocity sensors. Pressure sensors and their use in biomedicine. MEMS technologies and sensors.*	*PLO 10* *PLO 19* *PLO 5*	*Practical work 8* *Laboratory work 5*	*8th week*
Section № 6 Magnetic field sensors				
9	*Interaction of a magnetic field with a solid state. Influence of magnetic fields on the parameters of semiconductor devices. Hall effect. Magnetic resistors. Interaction of magnetic field with biological objects.*	*PLO 8* *PLO 9* *PLO 11*	*Practical work 9.* *Laboratory work 6*	*9th week*
Chapter № 7 Rigid Radiation Sensors				
10	Detectors based on gas ionization. Semiconductor detectors. Scintillation detectors.	*PLO 9* *PLO 11*	*Practical work 10* *Laboratory work 7*	*10th week*
Section № 8 Gas sensors				
11	Sorption sensors. QCM sensors. Humidity sensors. Calorimetric and catalytic methods for determining the gas composition. Optical and ultrasonic methods for determining the composition of gases. Ion-selective field-effect transistors and MDN varactors.	*PLO 9* *PLO 11*	*Practical work 11*	*11th week*
Section № 9 Sensors of physiological fluids				
12	Electrochemical methods of liquid research. Amperometric, potentiometric and conductometric sensors. Glucose, sweat, tear fluid and urea sensors. Biochemical and immune sensors. DNA-based sensors.	*PLO 5* *PLO 9* *PLO 11* *PLO 20*	*Practical work 12* *Laboratory work 8*	*12th week*
Section № 10 Biosensors and biochips				

13	Complexed sensors. The structure of biosensors. Biomedical nanosensors. Principles of construction of biochips. Electronic interfaces with biomedical facilities.	*PLO 9* *PLO 11* *PLO 20*	*MCT1* *Practical work 13*	*13th week*
14	Multi-parameter sensors "electronic nose" and "electronic tongue".	*PLO 8* *PLO 9* *PLO 11*	*Delivery of laboratory works*	*14th week*

Distribution of hours by types of training sessions

Sections and topics	Number of hours									
	Total	including								
		Lectures		PRACTICAL				Labs	Individual lessons	Individual work
				Seminars		Comput. practical				
		According to the curriculum	Classes	According to the curriculum		According to the curriculum	Classes			
1	2	3		4				5	6	7
Section 1. Sensory measurements										
1 Introduction. Terms and definitions. Errors. Classification of sensors. Active and passive sensors. Measurements in biomedicine. Measuring signal processing devices.	**10**	**2**		**2**		**0**				**6**
2 Schemes of signal formation of passive sensors. Schemes of inclusion of active sensors.	**10**	**2**		**2**		**0**				**6**
Together by section 1	**20**	**4**		**4**				**0**		**12**
Section №2 Features of designing biomedical sensors										
3 Biophysical signals. Measurement object activity and individual feature. Models and designs of biomedical electrodes. Areas of application of biomedical sensors.	**12**	**2**		**2**				**2**		**6**
Together by section 2	**12**	**2**		**6**		**0**		**2**		**6**

Sections and topics	Number of hours									
	Total	including								
		Lectures		PRACTICAL				Labs	Individual lessons	Individual work
				Seminars		Comput. practical				
		According to the curriculum	Classes	According to the curriculum		According to the curriculum	Classes			
Section №3 Optoelectronic and fiber-optic sensors										
4 Classification of fiber-optic sensors. Modern optoelectronic sensors. Features of pulse oximetry.	**16**	**2**		**2**				**2**		**10**
Together by section 3	**16**	**2**		**2**		**0**		**2**		**10**
Section № 4 Temperature sensors										
5 Thermoresistors. Thermocouple sensors. Temperature sensors on the photo effect. Dielectric temperature sensors. Temperature sensors based on semiconductor structures.	**14**	**2**		**2**				**2**		**8**
Together by section 4	**14**	**2**		**2**		**0**		**2**		**8**
Section № 5 Mechanical and acoustic sensors										
6 Acoustic research in medicine. Piezoelectric BAW and SAW sensors.		**2**		**2**				**2**		**2**
7 Registration of static and dynamic mechanical stresses. Tensor-resistant transducers, use of silicon to measure deformation.		**2**		**2**				**2**		**2**
8 Accelerometers. Flowmeter sensors. Linear and angular velocity sensors. Pressure sensors and their use in biomedicine. MEMS technologies and sensors.		**2**		**2**				**2**		**2**
Together by section 5	**22**	**6**		**6**		**0**		**6**		**6**
Section № 6 Magnetic field sensors										
9 Interaction of a magnetic field with a solid state. Influence of magnetic fields on the parameters of semiconductor devices. Hall effect. Magnetic resistors.		**2**		**2**				**2**		**4**

Sections and topics	Number of hours									
	Total	including								
		Lectures		PRACTICAL				Labs	Individual lessons	Individual work
				Seminars		Comput. practical				
		According to the curriculum	Classes	According to the curriculum		According to the curriculum	Classes			
Interaction of magnetic field with biological objects.										
Together by section 6	**8**	**2**		**2**		**0**		**2**		**4**
Chapter № 7 Rigid Radiation Sensors										
10 Detectors based on gas ionization. Semiconductor detectors. Scintillation detectors.		**2**		**2**				**2**		**2**
Together by section 7	**8**	**2**		**2**		**0**		**2**		**2**
Section № 8 Gas sensors										
Sorption sensors. QCM sensors. Humidity sensors. Calorimetric and catalytic methods for determining the gas composition. Optical and ultrasonic methods for determining the composition of gases. Ion-selective field-effect transistors and MDN varactors.		**2**		**2**						**2**
Together by section 8	**6**	**2**		**2**		**0**		**0**		**2**
Section № 9 Sensors of physiological fluids										
12 Electrochemical methods of liquid research. Amperometric, potentiometric and conductometric sensors. Glucose, sweat, tear fluid and urea sensors. Biochemical and immune sensors. DNA-based sensors.		**2**		**2**				**2**		**2**
Together by section 9	**8**	**2**		**2**		**0**		**2**		**2**
Section № 10 Biosensors and biochips										
13 Complexed sensors. The structure of biosensors. Biomedical nanosensors. Principles of construction of biochips. Electronic interfaces with biomedical facilities.		**2**		**2**						**4**
Multi-parameter sensors "electronic nose" and		**2**		**2**						

Sections and topics	Number of hours									
	Total	including								
		Lectures		PRACTICAL				Labs	Individual lessons	Individual work
				Seminars		Comput. practical				
		According to the curriculum	Classes	According to the curriculum		According to the curriculum	Classes			
"electronic tongue".										
Together by section 9	**14**	**4**		**4**		**0**		**0**		**4**
Exam	**2**	**2**								
Total:	**150**	**28**		**26**		**0**		**18**		**78**

Recommendations for mastering training sessions (in the form of a detailed description of each lesson and planned work):

Lecture classes

№ s/n	**Topics of classes**	**Number of hours**
1	*Lecture 1. Sensory measurements Scheduled: Introduction. Terms and definitions. Errors. Classification of sensors. Active and passive sensors. Practical: Measurements in biomedicine. Measuring signal processing devices. ISW topic: The role of sensors in biomedicine, diagnostics and medical equipment*	2 2
2	*Lecture 2. Schemes of inclusion of sensors.* *Scheduled: Schemes of signal formation of passive sensors. Schemes of inclusion of active sensors. Practical: Winston Bridge, generator circuits Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2 2
3	*Lecture 3. Features of biomedical sensors Scheduled: Biophysical signals. Measurement object activity and individual feature. Areas of application of biomedical sensors. Practical: Models and designs of biomedical electrodes. ISW topic: The role of sensors in biomedicine, diagnostics and medical equipment*	2 2

4	*Lecture 4. Optoelectronic sensors.* *Scheduled: Classification of fiber-optic sensors. Modern optoelectronic sensors. Features of pulse oximetry.* *Practical: Photofoltaic effect.* *Laboratory work №1. Optocouplers. Pulse oximeter study.* *Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2 2 2
5	*Lecture 5. Temperature sensors.* *Scheduled: Resistance thermometers. Thermocouple sensors. Temperature sensors on the photo effect. Dielectric temperature sensors. Temperature sensors on semiconductor structures. Practical: Pyroelectric effect.* *Laboratory work №2. Temperature sensors.* *Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2 2 2
6	*Lecture 6. Mechanical and acoustic sensors-1* *Scheduled:Acoustic research in medicine. Piezoelectric OAH and PAH sensors.* *Practical: Physical bases of piezoelectric effect Laboratory work №3. Piezoceramic vibration sensor.* *Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2 2 2
7	*Lecture 7. Mechanical sensors- 2* *Scheduled: Registration of static and dynamic mechanical stresses. Tensoresistor transducers, the use of silicon to measure deformation.* *Practical: Tensoresistive effect* *Laboratory work №4. Tensoresistive force sensor.* *Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2 2 2
8	*Lecture 8. Mechanical sensors – 3* *Scheduled: Accelerometers. Flow sensors. Linear and angular velocity sensors. Pressure sensors and their use in biomedicine. MEMS technologies and sensors.* *Practical: Laboratory work №5. Pressure sensors in tonometers and spirometers.* *ISW topic: The role of sensors in biomedicine, diagnostics and medical equipment*	2 2 2
9	*Lecture 9. Magnetic field sensors* *Scheduled: Interaction of the magnetic field with a solid body. Influence of magnetic fields on the parameters of semiconductor devices. Hall effect. Magnetic resistors.* *Practical: Interaction of magnetic field with biological objects.* *Laboratory work №6. Hall sensor.* *ISW topic: The role of sensors in biomedicine, diagnostics and medical equipment*	2 2 2

10	*Lecture 10. Sensors of hard radiation* *Scheduled: Detectors based on gas ionization. Semiconductor detectors. Scintillation detectors.* *Practical: Scintillation effect.* *Laboratory work №7. Geiger-Mueller counter* *ISW topic: The role of sensors in biomedicine, diagnostics and medical equipment*	2 2 2
11	*Lecture 11. Gas concentration sensors* *Scheduled: Sorption sensors. QCM sensors. Calorimetric and catalytic methods for determining the gas composition. Optical and ultrasonic methods for determining the composition of gases. Ion-selective field-effect transistors and MDN varactors. Practical: Humidity sensors. Laboratory work №8. Ion-selective field-effect transistors.* *Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2 2 2
12	*Lecture 12. Sensors of physiological fluids* *Scheduled: Electrochemical methods of liquid research. Amperometric, potentiometric and conductometric sensors. Glucose, sweat, tear fluid and urea sensors. Biochemical and immune sensors. DNA-based sensors.* *Practical: The current state of non-invasive glucometers.* *Laboratory work №9. pH sensor.*	2 2 2
13	*Lecture 13. Biosensors and biochips -1* *Scheduled: Folded sensors. The structure of biosensors. Biomedical nanosensors. Principles of construction of biochips.* *Practical: Electronic interfaces with biomedical objects.* *Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2 2
14	*Lecture 14. Biosensors and biochips -2* *Scheduled: Multi-parameter sensors "electronic nose" and "electronic tongue". Nanosensors in prosthetic of sensing organs.* *Practical: -* *Topic of ISW: Abstract review of Internet resources on the topic of the lecture. Preparation of analytical reference up to 5 pages.*	2
In total		**72**

Laboratory works

The performance of laboratory work is that the student has practically completed the technical task, made the necessary calculations and constructed graphical dependencies (if any). All laboratory work required by the curriculum is mandatory. Laboratory work is carried out in the interdepartmental training laboratory of Biomedical microelectronics "Microelectronic sensor systems" auditorium 147 12 building (scientific supervisor Prof. Orlov A.T.) created due to Grant project of the European Union TEMPUS - (2013-2017) "Biomedical Initiative Tempus in the Eastern Partnership region", № agreement - 543904-TEMPUS-1-2013-1-GR-TEMPUS-JPGR.

The list of laboratory works on the course:

1. *Laboratory work №1. Optocouplers. Pulse oximeter study.*
2. *Laboratory work №2. Temperature sensors.*
3. *Laboratory work №3. Piezoceramic vibration sensor.*
4. *Laboratory work №4. Tensor resistive force sensor.*
5. *Laboratory work №5. Pressure sensors in tonometers and spirometers.*

6. Laboratory work №6. Hall sensor.

7. Laboratory work №7. Geiger-Mueller counter

8. Laboratory work №8. Ion-selective field-effect transistors.

9. Laboratory work №9. PH sensor.

The defense of laboratory work involves the student's answer to 2… 4 questions on the topic of work. Protection of all laboratory work provided by the curriculum is mandatory.

6. Independent student work

Types of independent work: preparation for classroom classes is carried out in accordance with the discipline bar according to the links to the Google classroom platform, calculations when performing RGR on primary data, problem solving, essay writing, calculation work, modular control work, etc. to the teacher in electronic form through the Google classroom system and in terms of time specified in the system of current assessment. The student's independent work includes preparation for a modular test.

***Calculation and graphics work** is a current control measure, which covers practical skills in the application of schemes for the inclusion of active and passive sensors and their calculations and modeling of the sensor in the circuit.*

Approximate subject of calculation and graphic work:

1. *Design of a connection, normalizing, filtering and amplifying circuit for Optoelectronic sensor*
2. *Design of a connection, normalizing, filtering and amplifying circuit for Hall sensor;*
3. *Design of a connection, normalizing, filtering and amplifying circuit for tensoresistive sensor;*
4. *Design of a connection, normalizing, filtering and amplifying circuit for piezosensor;*
5. *Design of a connection, normalizing, filtering and amplifying circuit for thermocouple sensor;*
6. *Design of a connection, normalizing, filtering and amplifying circuit for thermoresistor;*
7. *Design of a connection, normalizing, filtering and amplifying circuit for pyroelectric sensor;*
8. *Design of a connection, normalizing, filtering and amplifying circuit for pH sensor;*
9. *Design of a connection, normalizing, filtering and amplifying circuit for CO2 sensor;*
10. *Design of a connection and amplifying circuit for Geiger-Mueller counter;*
11. *Design of a connection, normalizing, filtering and amplifying circuit for pressure sensor;*
12. *Design of a connection, filtering and amplifying circuit for conductometric sensor;*
13. *Design of a connection, normalizing, filtering and amplifying circuit for magneto resistor;*
14. *Design of a connection, normalizing, filtering and amplifying circuit for ampherometric sensor.*

The title page of the calculation and graphic work 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; theme of calculation and graphic work; 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 calculation and graphic work, 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 amount of calculation and graphic work, depending on the chosen topic can vary from 20 to 30 pages of the main text (in consultation with the teacher).

Mandatory requirement: clear reference to sources of information. All figures, facts, opinions of *scientists, quotations, formulas should 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 10 sources) is made out according to operating rules. If the information is taken from the Internet, you need, as for ordinary literature, specify the author, the title of the article, and then provide the address of the site on the Internet.*

Calculation and graphic work is evaluated by the following criteria: logic of the plan; completeness and depth of topic disclosure; reliability of the received data; reflection of practical materials and results of calculations; correctness of formulation of conclusions of the received results and conclusions; design; substantiation of the student's own opinion on this issue in the form of a conclusion.

Deadline for submission of calculation and graphic work for verification: 12th week of study.

Calculation and graphic 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)

Violation of deadlines and incentive points:

Incentive points		**Penalty points**	
Criterion	**Ваговий бал**	**Criterion**	**Weight score**
Performing practical work	***4***	***Violation of deadlines for practical work***	***1***
Timely writing of MCT	***0***	***Untimely writing of CGW or MCT***	***-5***
Timely passing of the exam	***0***	***Retake exam***	***-5***

Attending classes

Attendance at lectures, practical and field trips is not evaluated, for absence; they are awarded a penalty of 0.5 points. Students are encouraged to attend classes because they teach theoretical material and develop the skills needed to complete a semester individual assignment. The grading system focused on obtaining points for student activity, as well as performing tasks that are able to develop practical skills and abilities. Missed control measures must be rescheduled before the end of the certification week. The thematic task, which submitted for inspection in violation of the deadline - inot evaluated.

Academic integrity

The policy and principles of academic integrity 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 "Medical Microprocessor Systems" can be taught to most students with special educational needs, except for students with severe visual impairments who do not allow performing tasks using personal computers, laptops and / or other technical means.

Distant learning

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

Distant 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 teacher offers the list of courses 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 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 in 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)[1]

[1] Вимоги до РСО та методика її складання надані у Положенні про рейтингову систему оцінювання результатів навчання студентів / Уклад.: В. П. Головенкін. – К.: НТУУ «КПІ», 2012. – 36 с.

Rating system by types of classes:

№ s/n	Subject classes rating	the total number of tasks	The maximum score for 1 task	Number of points for "excellent"
1.	***Lectures: visiting taking notes***	***14*** ***1***	***2*** ***12***	***28*** ***12***
	Laboratory works: timely	***5***	***2***	***10***

2.	***execution***	***5***	***2***	***10***
	Practical works: timely execution	***12*** ***2***	***2*** ***2***	***10*** ***10***
3.	***Modular control tests***	***2***	***10***	***20***
4.	***Calculation and graphics work: timely execution***	***1***	***10***	***10***
Semester points		***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 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.

Mandatory condition for admission		**Criterion**[2]
	Current rating. Execution of RGR.	*RD ≥ 20*
	Writing a modular test	*RD ≥ 60*
	Total	*RD ≥ 80*

[2] Assessment of learning outcomes is carried out according to the rating system of assessment in accordance with the recommendations of the Methodical Council of KPI. Igor Sikorsky, approved by the protocol №7 dated March 29, 2018.

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

Number points	**Assessment on the university scale**
100-95	*Perfectly / Відмінно*
94-85	*Very good / Дуже добре*
84-75	*Good / Добре*
74-65	*Satisfactorily / Задовільно*
64-60	*Enough / Достатньо*

Less 60	*Unsatisfactorily / Незадовільно*
Admission conditions are not met	*Not allowed / Не допущено*

9. Additional information on the discipline (educational component)

Distance learning through additional online courses on certain topics 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).

• Possible enrollment of certificates for distance or online courses on relevant topics;

• Other information for students/graduate students about the peculiarities of mastering the discipline.

Professor of the Department of Microelectronics Orlov A.T. was the coordinator of the project of the European Union TEMPUS - (2013-2017) "Biomedical engineering educational initiative Tempus in the Eastern Partnership region", № agreement - 543904-TEMPUS-1-2013-1-GR-TEMPUS-JPGR because of which the master's specialty was implemented 153 "Biomedical Engineering" at the Faculty of Biomedical Engineering KPI. Igor Sikorsky. Member of the Organizing Committees of the International Conferences IEEE "ELNANO (Electronics and Nanotechnology)" and IFMBE (International Conference Health Technology Management) (Moldova).

A certificate confirms knowledge of English at B2 level: № 25524; First Kyiv state courses 2019-09-17 ÷ 2020-01-24; Number of hours: 620.

Work program of the discipline (syllabus):

***Compiled by** Associate Professor of Microelectronics. Candidate of Technical Sciences (PhD), Anatolii T. ORLOV, Professor and Head of the Department of Microelectronics.*

***Approved by** the Department of Biomedical Engineering (protocol № ___ to ____________)*

***Approved by** the Methodical Commission of the Faculty of Biomedical Engineering (protocol № __ to _______)*