National Technical University of Ukraine
«IGOR SIKORSKY
KYIV POLYTECHNIC INSTITUTE

Department of Biomedical Engineering

MEASURING CONVERTERS AND SENSORS

Syllabus

Requisites of the discipline

Level of high education	***First (bachelor's)***
Branch of knowledge	*16 Chemical and bioengineering*
Specialty	*163 Biomedical Engineering*
Educational program	*Medical engineering*
Status of the discipline	*Selective*
Learning form	*full-time / day / mixed / remote*
Semester	*3h year, spring semester*
Course scope	*4 credits / 120 hours*
Semester control / control measures	*Test, modular control work*
Schedule	*According to the schedule on the website http://rozklad.kpi.ua/*
Language	*English*
Information about course supervisor and lecturers	***Lecturer:*** *Associate Professor of Biomedical Engineering, PhD of Technical Sciences, Dubko Andrii Grigorovich,* *intellect.kpi.ua/profile/dag5;* *http://www.nas.gov.ua/UA/PersonalSite/Pages/default.aspx?PersonID=0000016737* *http://orcid.org/0000-0001-6070-3945* *https://www.scopus.com/authid/detail.uri?authorId=55226164600.* ***Practical:*** *Associate Professor of Biomedical Engineering, PhD of Technical Sciences, Dubko Andrii Grigorovich,* *intellect.kpi.ua/profile/dag5;* *http://www.nas.gov.ua/UA/PersonalSite/Pages/default.aspx?PersonID=0000016737* *http://orcid.org/0000-0001-6070-3945* *https://www.scopus.com/authid/detail.uri?authorId=55226164600.*
Course placement	*Sikorsky Platform - course " Measuring converters and sensors"*

Curriculum of the discipline

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

The subject of the discipline " Measuring converters and sensors" is to form students' understanding of the principles, skills and practical skills in the study and development of measuring transducers and sensors.

The purpose of teaching the discipline is to provide students with theoretical knowledge and the formation of practical skills in the ability to solve complex specialized problems and practical problems of creation, operation, and testing of medical devices with sensors and converters.

The objectives of the discipline are:

- mastering the general principles of use of regulations and methodological bases of metrological measurements;
- analysis of the current state of measuring transducers and sensors during biomedical measurements;
- mastering knowledge of measuring instruments and methods, types of standards, calibration and verification of measuring instruments;
- mastering the procedure and procedure for ensuring the unity of measurements;
- mastering knowledge of methods to reduce measurement errors.
- mastering knowledge about obstacles and methods of combating them.

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 *2 - Knowledge and understanding of the subject area and understanding of professional activity.*
GC *3 - Ability to communicate in the state language both orally and in writing.*
GC *6 - Ability to search, process and analyze information from various sources.*
GC *9 - Ability to communicate with representatives of other professional groups of different levels (with experts from other fields of knowledge / types of economic activity).*

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

PC2- Ability to provide engineering expertise in the process of planning, development, evaluation and specification of medical equipment.
PC 6- Ability to effectively use tools and methods for analysis, design, calculation and testing in the development of biomedical products and services.
PC13- Ability to ensure and monitor compliance with safety and biomedical ethics when working with medical equipment.

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

PLO 3 Knowledge of design tools for devices, devices and systems for medical and biological purposes.
PLO 4 Knowledge of methods of designing digital and microprocessor systems for medical purposes.
PLO 7 Understanding of scientific and technical principles that underlie the latest advances in biomedical engineering.
PLO 18 The use of practical methods of organization to solve engineering and scientific and practical problems of different levels of complexity.
PLO 24 Apply knowledge of the basics of mathematics, physics and biophysics, bioengineering, chemistry, engineering graphics, mechanics, resistance and strength of materials, properties of gases and liquids, electronics, computer science, obtaining and analyzing signals and images, automatic control, systems analysis and decision making methods at the level required to solve the problems of biomedical engineering.
PLO 31 Understanding of theoretical and practical approaches to the creation and management of medical equipment and medical equipment.
PLO 36 Analysis of signals transmitted from organs to devices, and receipt and processing of diagnostic information.

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

The discipline "" Measuring converters and sensors" belongs to the cycle of professional training and has an interdisciplinary nature. It integrates according to its subject knowledge from other disciplines: Electrical Engineering and Electronics; Analog and digital circuitry. According to the structural and logical scheme of the training program, the discipline " Measuring converters and sensors" is closely related to other disciplines in modern research in the specialty, including disciplines: Devices for monitoring human physiological parameters; Pre-diploma practice.

3.The content of the discipline

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

Section 1. General information on measuring equipment

Topic 1.1. The role and importance of measuring equipment
Topic 1.2 Basic concepts and definitions.
Topic 1.3. Physical quantities. Fundamentals of metrology and standardization
Topic 1.4. Types and methods of measurements
Topic 1.5. Classification and characteristics of measuring instruments
Topic 1.6. Structures of measuring instruments

Section 2. Classification of measurement errors and methods of their normalization, accuracy classes of measuring instruments, normalized metrological characteristics of measuring instruments

Topic 2.1. Classification of measurement errors.
Topic 2.2. Standardization of measuring instruments by errors
Topic 2.3 Accuracy classes of measuring instruments

Section 3. Standards, measures of electrical and magnetic quantities

Topic 3.1. Standards
Topic 3.2. Measures of electrical quantities

Section 4. Passive measuring transducers of the II kind

Topic 4.1. Shunts
Topic 4.2. Voltage dividers
Topic 4.3. Measuring transformers of alternating current

Section 5. Active measuring transducers of the II kind

Topic 5.1. Amplifier feedback
Topic 5.2. AC amplifiers
Topic 5.3. DC amplifiers

Section 6. Measuring transducers of the first kind

Topic 6.1. Parametric measuring transducers
Topic 6.2. Generator measuring transducers

Section 7. Analog-to-digital and digital-to-analog converters

Topic 7.1. Basic concepts and definitions
Topic 7.2 Principles of analog-to-digital conversion
Topic 7.3. Digital-to-analog converters

Section 8. Methods of reducing measurement errors

Topic 8.1. Negative feedback method
Topic 8.2. Auxiliary measurement method
Topic 8.3 Iterative methods

Topic 8.4 Methods of exemplary measures
Topic 8.5. Test methods

Section 9. Interference. Methods of combating interference

Topic 9.1. Types of interference, assessment of noise immunity
Topic 9.2. Combating general interference

4. Learning materials and resources

Basic literature, which should be used to master the discipline, is developed independently to prepare forpractical classes and in the context of distance learning. It is suggested to use additional literature and Internet resources to perform modular tests, prepare reports, presentations, write essays based on the results of independent work.

1. *Introduction to Sensors, Instrumentation, and Measurement. Brian D. Storey. Olin College. – 2018. – 112p.*
2. *Medical Devices and Human Engineering. Edited by: Joseph D. Bronzino, Donald R. Peterson. © Taylor & Francis Group - 2015. 858 p.*
3. *Jacob Fraden. Handbook of Modern Sensors. Physics, Designs, and Applications. Fourth Edition. Springer ScienceþBusiness Media, - 2010. – 663 p.*
4. *ENGINEERING METROLOGY AND MEASUREMENTS. N.V. RAGHAVENDRA, L. RISHNAMURTHY. Oxford University Press 2013. – 531 p.*
5. *Biomedical Sensors and Instruments. Tatsuo Togawa, Toshiyo Tamura, P. Ake Oberg. © 2011 by Taylor and Francis Group, LLC- 398p.*
6. *Modern sensors handbook/edited by Pavel Ripka, Alois Tipek. ISTE Ltd, 2007. – 518p.*
7. *Measurement Systems and Sensors. Waldemar Nawrocki. ARTECH HOUSE, INC. 2005. -325 p.*
8. *Measurement, Instrumentation, and Sensors. Handbook.* 1999 by CRC Press LLC- 2587 p.
9. *Medical Device Design. Innovation from Concept to Market . First edition. Peter J. Ogrodnik.. Academic Press is an imprint of Elsevier - 2013. Kidlington, Oxford. 275 p.*

Educational content

5. Methods of mastering the discipline (educational component)

№ s/n	Subject	Program learning outcomes	The main tasks	
			Control measure	Deadline
1.	Physical quantities. Fundamentals of metrology and standardization	PLO 24 PLO 31	Practical work 1	1-2nd week
2.	Accuracy classes of measuring instruments	PLO 18 PLO 31	Practical work 2	3-4th week
3.	Measures of electrical quantities	PLO 4 PLO 31	Practical work 3	5-6th week
4.	Shunts	PLO 24 PLO 36	Practical work 4	7-8th week
5.	Measuring transformers of alternating current	PLO 18 PLO 24 PLO 36	Practical work 5	9-10th week
6.	Amplifier feedback	PLO 31	Practical work 6	11th week
7.	Generator measuring transducers	PLO 24 PLO 31	Practical work 7	12-13th week
8.	Modular control work	PLO 7	Writing a modular test	14th week
9.	Home control work	PLO 18	Registration and submission of work	15-16th week

6. Independent student work

One of the main types of semester control during the mastering of the discipline " Measuring converters and sensors" is the performance of home control work. Homework is performed in accordance with the requirements, within the period specified by the teacher.

The main purpose of homework is to solve a practical problem using the material learned in lectures and independently, and practical skills acquired in practical classes. The student can write homework only on the subject agreed with the teacher.

Approximate topics of home control work:

№1 Physical phenomena and energy transformations that used in sensors
№2 Measurement and conversion of physical quantities
№3 Optoelectronic sensors
№4 Strain gauges.
№5 Electromagnetic sensors
№6 Temperature sensors. Thermistors
№7 Piezoelectric sensors
№8 Multisensory electronic odor and taste detectors
№9 Trends in the development of sensors of physical quantities and methods of measurement in biometrics

The title page of the homework 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 home control work; last name and first name of the student, course, number of the academic group, year.

The title page is followed by a detailed plan (content) of homework, 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 homework depending on the chosen topic can vary from 25 to 40 pages of the main text (in consultation with the teacher). The amount of homework is determined by the student's ability to briefly and comprehensively explain the results.

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 bibliography 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, to indicate the author, the title of the article, and then provide the address of the site on the Internet.

Homework is evaluated by the following criteria: the logic of the plan; completeness and depth of disclosure of the topic; 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 submitting homework for review: 16th week of study.

Homework 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 practical 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.

Home control work, 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*
Improving practical work	*1 points (for each practical work)*	*Untimely implementation and test of practical work*	*From -0.5 points to -5 points (depending on the delivery date)*
Passing distance courses on topics	*5 points*	*Untimely execution and*	*From -2 points to -*

that are agreed with teachers		*test of calculation and home work*	*20 points (depending on the construction period)*
Registration of scientific work for participation in the competition of student scientific works	*10 points*		
Writing abstracts, articles, participation in international, national and / or other events or competitions on the subject of the discipline	*5 points*		

** 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 course "Measuring Transducers and Sensors" can be taught to most students with special educational needs, except for students with severe visual impairments who are not allowed to perform tasks using personal computers, laptops and / or other technical means.

Distance learning

Distance learning takes place through the Sikorsky Distance Learning Platform.

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).

Execution of practical work, as well as homework, is carried out during the independent work of students in the remote mode (with the possibility of consulting with the teacher via 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):

№ s/n	Control measure	%	Weight points	Number	Total
1.	Express control works / test tasks	21	1,5	14	21
2.	Execution and protection of practical works	21	3	7	21
3.	Modular control work	8	8	1	8
4.	Home control work	10	10	1	10
5.	Test	40	40	1	40
				Total	100

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		≥ 24 points	≥ 40points
	Execution practical work	PW №№1-4	+	+
		PW №№5-7	-	+
	Express control works / test tasks	At least 4 of any lectures	+	-
		At least 10 of any lectures	-	+
	Modular control work	Estimated MCW	-	+
	Home control work	Evaluated HCW	-	-

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 exam	***Критерій***
1	*Current rating*	*RD ≥ 30*
2	*Obtaining a positive assessment for the performed calculation and graphic work*	*More than 6 points*
3	*All practical works are tested*	*More than 6 points*
4	*Writing at least 6 express tests / tests*	*More than 6 points*

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

Mandatory conditions for admission to the exam:
1. Activity in practical classes.
2. Positive result of the first attestation and the second attestation.
3. Attending lectures.

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*

The test is held orally.

9. Additional information on the discipline (educational component)

The list of questions for preparation for modular control work, and also for preparation for examination 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 of Biomedical Engineering, PhD of Technical Sciences, Dubko Andrii Grigorovich.*

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

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

Appendix 1 to the syllabus of the discipline

" Measuring converters and sensors "

The list of questions for preparation for modular control work,

as well as to prepare for the test

1. Define what is measurement and the principle of measurement?
2. Define what is measurement error, measurement accuracy and measurement principle.
3. Define what is a measuring experiment, measuring instrument - (SV), measurement method. ?
4. Define what is the unity of measurements and metrology?
5. What does the physical quantity reflect? Write down the basic equation of measurement.
6. List the basic physical quantities in the International System of Units SI.
7. How to reduce the loss of measurement information?
8. What kinds (types) of measurements do you know?
9. Explain the principles of direct and indirect (side) types of measurements.
10. Explain the principles of aggregate and compatible measurements.
What are the measurement methods?

10. *Explain the method of direct evaluation of the measurement result. Explain the method of comparison with measure.*
11. *Explain the method of substituting the measured value. Explain the method of coincidences.*
12. *What are the types of measuring instruments?*
13. *What are the characteristics of the assessment of measuring instruments?*
14. *Give the structure of the measuring instrument in general.*
15. *Define the absolute measurement error.*
16. *Define the relative measurement error.*
17. *What are the divisible measurement errors depending on the reasons for their occurrence?*
18. *How does an instrumental error occur?*
19. *What causes a methodological error?*
20. *Explain what caused the subjective error.*
21. *Define what is a systematic, accidental mistake and omission.*
22. *Standards of measuring instruments.*
23. *Define what is a measuring transducer?*
24. *Define what is a type II measuring transducer (scale measuring transducer)?*
25. *Define what is a measuring transducer of the first kind (sensor)?*
26. *What are the types of scale converters?*
27. *What are shunts used for?*
28. *Voltage dividers.*
29. *Measuring current and voltage transformers.*
30. *Amplifiers.*
31. *Amplifier feedback.*
32. *AC amplifiers.*
33. *DC amplifiers.*
34. *Parametric measuring transducers.*
35. *Rheostatic converters (resistive).*
36. *Inductive converters.*

37. *Capacitive converters.*
38. *Generator measuring transducers.*
39. *Induction converters.*
40. *Thermoelectric converters (thermocouples).*
41. *How do pyrometers work?*
42. *How do digital transducers (DACs) work?*
43. *Explain the principles of analog-to-digital conversion.*
44. *How do digital-to-analog converters work?*