Syllabus
educational component

Intelligent sensors

Name of the discipline:	**Intelligent sensors**
Higher education level:	**First (bachelor's)**
Course page in Moodle:	*https://dl2022.khadi-kh.com/course/view.php?id=2949*
Scope of the educational component	**4 credits (120 hours)**
Form of final control	**Passed**
Consultations:	**on schedule**
Name of the department:	**Department of Metrology and Life Safety**
Language of instruction:	**English**
Course Leader:	**Andrii Koval, k. Ph.D., Associate Professor**
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Summary of the educational component:
The goal is to develop research skills in the field of theory and methodology of building intelligent sensors, assimilation of new theoretical knowledge about modern models of intelligent sensors, acquisition of practical skills and abilities to apply basic methods and approaches to identify the causes and search for sources of uncertainty in measurements of intelligent sensors of on-board measuring systems of cars and road machines.
Subject*:* theoretical and methodological foundations of the construction of intelligent sensors.
The main tasks of studying the discipline are:
– substantiation and presentation of uniform theoretical and methodological foundations of the principles of building intelligent sensors;
– study of the methodology for building intelligent sensors;
– formation of directions for the improvement and development of intelligent sensors of on-board measuring systems of cars and road machines;
– formation of skills for organizing independent research work and presentation of scientific research results.

Prerequisites for studying the educational component:
Functional devices of measuring information systems, Fundamentals of metrology and measuring technology.

Competencies that the applicant acquires:
***General competencies*:**
Ability to abstract thinking, analysis, synthesis and application of knowledge in practical situations;
Ability to search, process and analyze information from various sources, the use of information and communication technologies;
Ability to learn and master modern knowledge, ability to identify, pose and solve problems;
Special (professional) competencies:
Ability to analyze the components of error according to their essential features, operate with the components of error/uncertainty in accordance with measurement models.
Ability to design information and measuring equipment and describe the principle of their operation.
Ability to apply basic knowledge of methods and measures aimed at ensuring, maintaining and increasing the reliability of data processing of measurement, testing and

control of products at all stages of their life cycle, as well as the study of modern information and analytical technologies for data processing.

Learning outcomes:

Be able to use information technologies, software and the Internet in solving specific problems of professional activity.

Be able to find reasonable solutions when drawing up structural, functional and schematic diagrams of information and measuring equipment.

Know and understand the basic concepts of metrology, measurement theory, mathematical and computer modeling, modern methods of processing and evaluating the accuracy of a measuring experiment.

Thematic plan

Topic No.	Name them (LK, LZ, PZ, SZ, SR)	Number of hours
		Full-time
1	LC1. The concept and place of intelligent sensors in intelligent information and measurement systems. Evolution of measuring sensors. Criteria of intellectuality. Intelligence levels in IIS. Sensor as a primary carrier of measuring intelligence	2
	PZ1. Comparative analysis of traditional and intelligent sensor.	2
	SR1. Analysis of modern intelligent sensors according to technical documentation (datasheet)	11
	LC2. Intelligent sensor architecture. Functional blocks. Distribution of hardware and software functions. Built-in microcontroller / DSP. Information flows inside the sensor	2
	PZ2. Simulation of the measuring channel of the intelligent sensor. Primary converter. ADC. Digital processing.	2
	SR2. Simulation of the structure and functional blocks of an intelligent sensor.	11
2	LC3. Metrological characteristics of intelligent sensors. Static MX. Dynamic MX. The impact of digital processing on MX. Transition from sensor characteristics to measurement result characteristics.	2
	Software 3 Study of analog-to-digital conversion parameters.	2
	SR3. Metrological consequences of digitization of measuring signals	11
	LC4. Analog-to-digital conversion in smart sensors. Quantization and Discretization. ADC error sources. Influence of bit depth and sample rate. Total error of the measuring channel.	2
	PZ4. Estimation of the effect of ADCs on measurement error and uncertainty.	2
	SR4. Numerical simulation of analog-to-digital conversion.	11
3	LC5. Algorithms for linearization and error compensation. Compensation for nonlinearity. Temperature compensation. Offset and sensitivity correction. Program tables and approximation models.	2
	PZ5. Algorithmic linearization and nonlinearity compensation.	2
	SR5. Algorithmic linearization and compensation of static errors.	11

	LC6. Digital filtering and noise reduction in smart sensors. Types of noise in sensors. Filtration as an element of the sensor. The effect of filtering on dynamic error. The "noise - speed" compromise.	2
	PZ6. Digital filtering research in an intelligent sensor.	2
	SR6. Digital filtering and dynamic error analysis.	11
	LC7. Self-diagnosis and metrological reliability of smart sensors. Principles of self-control. Signs of degradation. Control of noise parameters. Indicators of reliability of results.	2
	PR7. Time series analysis for sensor self-diagnosis.	2
	SR7. Self-diagnosis and assessment of metrological reliability of smart sensors.	11
4	LC8. Measurement uncertainty and the role of intelligent methods. Error and uncertainty of ID. Built-in measurement uncertainty estimation in ID. Reducing uncertainty through algorithms. Intelligent sensor as part of IIS and IoT.	2
	PZ8. Uncertainty estimation and structural synthesis of the intelligent sensor.	2
	SR8. System synthesis of the intelligent sensor.	11
Total	LC	16
	PR	16
	WED	88

Teaching methods:
MH1 – verbal method (lecture, educational discussion, explanation, story);
MH2 – practical method (practical classes);
MH3 – visual method (method of illustrations, method of demonstrations);
MH4 – work with literature (educational and methodological; normative literature; search for information on the task);
MH5 – video method in combination with the latest information technologies and computer learning tools (distance);
MH6 – independent work;

Forms and methods of assessment
FMO2 – final control (credit)
FMO4 – written control (individual tasks)
FMO5 – test control (standardized tests, final complex tests)
FMO7 – practical test (defense of practical works)

Grading System and Requirements:

Assessment in the discipline and its transfer into grades on the national scale and the ECTS scale is carried out in accordance with STVNZ 90.1-02:2023 "Assessment of the learning outcomes of higher education applicants".

Current Academic Performance

1 The current performance of applicants for the performance of educational types of work in training classes and for the performance of tasks of independent work is evaluated using a four-point scale of assessments with subsequent recalculation in a 100-point scale. When assessing current performance, all types of work provided for by the curriculum are taken into account.

1.1 Lectures are evaluated by determining the quality of performance of specified tasks.

1.2 Practical classes are evaluated by the quality of performance of a control or individual task, performance and design of practical work.

2 Assessment of the current performance of higher education applicants is carried out at

each practical lesson on a four-point scale ("5", "4", "C", "2") and is entered into the journal of academic performance.

– "excellent": applicant has mastered the theoretical material impeccably, demonstrates deep knowledge of the relevant topic or academic discipline, the main provisions;

– "good": the applicant has mastered the theoretical material well, knows the main aspects from primary sources and recommended literature, presents it in a reasoned manner; has practical skills, expresses his thoughts on certain problems, but makes certain inaccuracies and errors in the logic of presenting theoretical content or in the analysis of practical content;

– "satisfactory": the applicant has mainly mastered the theoretical knowledge of an educational topic or discipline, is guided by primary sources and recommended literature, but answers unconvincingly , confuses concepts, uncertainly answers additional questions, does not have stable knowledge; when answering questions of a practical nature, reveals inaccuracy in knowledge, does not know how to evaluate facts and phenomena, associate them with the future profession;

– "unsatisfactory": the applicant has not mastered the educational material of the topic (discipline), does not know scientific facts, definitions, almost does not know the primary sources and recommended literature, there is no scientific thinking, practical skills are not formed.

3 The final score for the current activity is recognized as the arithmetic mean sum of points for each lesson, for individual work according to the formula:

$$K^{nomoч} = \frac{K1 + K2 + ... + Kn}{n},$$

where $K^{nomoч}$ is the final assessment of success based on the results of current control;

$K1, K2, ..., Kn$ – assessment of the success n of the current control measure;

n – the number of current control measures.

Grades are converted into points according to the conversion scale (Table 1).

Table 1 – Recalculation of the average score for current activities into a multi-point scale

4-point Scale	100- point Scale	4- Point Scale	100-point Scale	4- Point Scale	100-point Scale	4- Point Scale	100-point Scale
5	100	4,45	89	3,90	78	3,35	67
4,95	99	4,4	88	3,85	77	3,3	66
4,9	98	4,35	87	3,80	76	3,25	65
4,85	97	4,3	86	3,75	75	3,2	64
4,8	96	4,25	85	3,7	74	3,15	63
4,75	95	4,20	84	3,65	73	3,1	62
4,7	94	4,15	83	3,60	72	3,05	61
4,65	93	4,10	82	3,55	71	3	60
4,6	92	4,05	81	3,5	70	1.78 to 2.99	35 to 59
						Reassembly	
4,55	91	4,00	80	3,45	69	0 to 1.77	0 to 34
4,5	90	3,95	79	3,4	68	Re-study	

Final assessment

1 A higher education applicant receives a credit at the last lesson in the discipline according to the results of the current assessment. The average grade for the current activity is converted into points on a 100-point scale, according to the conversion table (Table 1).

Applicants for higher education education, who have an average Current Evaluation With the Help disciplines lower than "3" (60 points), On the other hand the last classes can increase their current score by taking tests With the Help discipline.
Assessment of applicants' knowledge by testing is carried out on a scale:

– "Excellent": at least 90% of correct answers;
– "Very good": from 82% to 89% of correct answers;
– "Good": from 74% to 81% of correct answers;
– "Satisfactory": from 67% to 73% of correct answers;
– "Satisfactory enough": from 60% to 66% of correct answers;
– "Unsatisfactory": less than 60% of correct answers.

2 The condition for obtaining The offset is:
– working out all missed classes;
– average current grade in the discipline not lower "3" (60 points).
3 For the performance of individual independent work and participation in scientific events, applicants are awarded additional points.
3.1 Additional points are added to the sum of points scored by the applicant for higher education for the current educational activity (for disciplines, the final form of control for which is a test), or to the final grade in the discipline, the final form of control for which is an exam.
3.2 The number of additional points awarded for different types of individual tasks depends on their volume and significance:

– prizes in the discipline at the international/all-Ukrainian competition of scientific student works – 20 points;
– prizes in the discipline at the All-Ukrainian Olympiads – 20 points;
– participation in the international/all-Ukrainian competition of scientific student works – 15 points
– participation in international/all-Ukrainian scientific conferences of students and young scientists – 12 points;
– participation in all-Ukrainian Olympiads in the discipline – 10 points
– participation in Olympiads and scientific conferences of KhNAHU in the discipline – 5 points;
– performance of individual research (educational and research) tasks of increased complexity – 5 points**.**

3.3 The number of additional points cannot exceed 20 points.
4 The learning outcome is evaluated *(choose the one you need):*
– on a 100-point scale (for a differentiated test) according to Table 3.
The final grade, together with additional points, cannot exceed 100 points.

Table 2 – Scale of assessment of applicants' knowledge based on the results of the final control in the academic discipline

Score in points	National scale score		ECTS score	
			Evaluation	Criteria
	Exam	Credit		
90-100	**Excellent**	**Zarakhovano**	**A**	The theoretical content of the course has been mastered completely, without gaps, the necessary practical skills in working with the mastered material have been formed, all the educational tasks provided for by the training program have been completed, the quality of their implementation has been evaluated by the number of points close to the maximum

Score in points	National scale score		ECTS score	
	Exam	Credit	Evaluation	Criteria
80–89	**Good**	**Zarakhovano**	**B**	The theoretical content of the course is mastered completely, without gaps, the necessary practical skills of working with the mastered material are basically formed, all the educational tasks provided for by the training program are completed, the quality of most of them is evaluated by the number of points close to the maximum
75-79			**S**	The theoretical content of the course is mastered completely, without gaps, some practical skills of working with the mastered material are not sufficiently formed, all the educational tasks provided for by the training program have been completed, the quality of performance of any of them has not been evaluated by the minimum number of points, some types of tasks have been completed with errors
67-74	**Satisfactory**		**D**	The theoretical content of the course has been partially mastered, but the gaps are not significant, the necessary practical skills in working with the mastered material have been largely formed, most of the educational tasks provided for by the training program have been completed, some of the completed tasks may contain errors
60–66			**And**	The theoretical content of the course has been partially mastered, some practical work skills have not been formed, many of the training tasks provided for by the training program have not been completed, or the quality of some of them has been evaluated by the number of points close to the minimum.
35–59	**Unsatisfactory**	**Not Credited**	**FX**	The theoretical content of the course has been partially mastered, the necessary practical skills have not been formed, most of the provided training programs for educational tasks have not been completed, or the quality of their implementation has been evaluated by the number of points close to the minimum; With additional independent work on the course material, it is possible to improve the quality of educational tasks (with the possibility of re-compiling)
0–34	**Unacceptable**		**F**	The theoretical content of the course has not been mastered, the necessary practical skills have not been formed, all completed training tasks contain gross errors, additional independent work on the course material will not lead to any significant improvement in the quality of educational tasks (with the obligatory repeated course)

Course Policy:

– the course involves teamwork, the environment in the classroom is friendly, creative, open to constructive criticism;

– mastering the discipline involves mandatory attendance at lectures and practical classes, as well as independent work;

– independent work involves the study of individual topics of the academic discipline, which are submitted in accordance with the program for independent study, or were considered briefly;

– all tasks provided for by the program must be completed on time;
– if the applicant for higher education is absent from classes for a good reason, he/she presents the completed tasks during self-preparation and consultation with the teacher;
– during the study of the course, applicants for higher education must comply with the rules of academic integrity set forth in the following documents: "Rules of academic integrity of participants in the educational process of KhNAHU" (https://www.khadi.kharkov.ua/fileadmin/P_Standart/pologeniya/stvnz_67_01_dobroch_1.pdf), "Academic integrity. Checking the text of academic, scientific and qualification papers for plagiarism" (https://www.khadi.kharkov.ua/fileadmin/P_Standart/pologeniya/stvnz_85.1-02.pdf), "Moral and ethical code of participants in the educational process of KhNAHU (https://www.khadi.kharkov.ua/fileadmin/P_Standart/pologeniya/stvnz_67_01_MEK_1.pdf).
– in case of detection of the fact of plagiarism, the applicant receives 0 points for the task and must re-complete the tasks provided for in the syllabus;
– cheating during tests and exams is prohibited (including the use of mobile devices). Mobile devices are allowed to be used only during online testing.

Recommended reading:

1. Measuring transducers (sensors): textbook / Vanko V. M., Polishchuk E. S., Dorozhovets M. M., Yatsuk V. O., Yatsuk Yu. Lviv: Lviv Polytechnic National University Publishing House, 2015. 584 p. (in Russian).
2. Koval A. O. Intellectual sensors: lecture notes. Electronic resource. Kharkiv National Automobile and Highway University. Kharkiv, 2024. 94 p. URL: https://griml.com/rc1Ry. (accessed 21.08.2024).
3. Koval O. A. Optimization methods in measuring information systems: lecture notes. Electronic resource. Kharkiv National Automobile and Highway University. Kharkiv, 2024. 88 p. URL: https://griml.com/26b8u. (accessed 21.08.2024).

Additional sources:

1. Distance Course: https://dl2022.khadi-kh.com/course/view.php?id=2949.

Developer
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