UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2023/2024
MASTER'S DEGREE (MSC)	CYBER-PHYSICAL SYSTEMS ENGINEERING FOR INDUSTRY
INTEGRATED COURSE	AUTOMATIC MEASUREMENT SYSTEMS AND SENSORS - INTEGRATED COURSE
CODE	21509
MODULES	Yes
NUMBER OF MODULES	2
SCIENTIFIC SECTOR(S)	ING-INF/07, ING-IND/12
HEAD PROFESSOR(S)	COSENTINO VALENTINA — Professore Ordinario — Univ. di PALERMO
OTHER PROFESSOR(S)	D'ACQUISTO LEONARDO — Professore Ordinario — Univ. di PALERMO COSENTINO VALENTINA — Professore Ordinario — Univ. di PALERMO
CREDITS	9
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	2° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**COSENTINO VALENTINA** Monday 10:00 17:00 In presenza / In person: Laboratorio didattico misure elettriche, Edifico 9, piano terra, stanza S09PT062 (ex U030) / Electrical measurement teaching lab, Building 9, ground floor, room S09PT062 (ex U030). A distanza / Remotely: Teams call. RICEVIMENTO PREVIO APPUNTAMENTO VIA EMAIL O CHAT TEAMS / APPOINTMENT IS NEEDED, BY EMAIL OR TEAMS CHAT Tuesday 10:00 17:00 In presenza / In person: Laboratorio didattico misure elettriche, Edifico 9, piano terra, stanza S09PT062 (ex U030) / Electrical measurement teaching lab, Building 9, ground floor, room S09PT062 (ex U030). A distanza / Remotely: Teams call. RICEVIMENTO PREVIO APPUNTAMENTO VIA EMAIL O CHAT TEAMS / APPOINTMENT IS NEEDED, BY EMAIL OR TEAMS CHAT Wednesday 10:00 17:00 In presenza / In person: Laboratorio didattico misure elettriche, Edifico 9, piano terra, stanza S09PT062 (ex U030) / Electrical measurement teaching lab, Building 9, ground floor, room S09PT062 (ex U030). A distanza / Remotely: Teams call. RICEVIMENTO PREVIO APPUNTAMENTO VIA EMAIL O CHAT TEAMS / APPOINTMENT IS NEEDED, BY EMAIL OR TEAMS CHAT Thursday 10:00 17:00 In presenza / In person: Laboratorio didattico misure elettriche, Edifico 9, piano terra, stanza S09PT062 (ex U030) / Electrical measurement teaching lab, Building 9, ground floor, room S09PT062 (ex U030). A distanza / Remotely: Teams call. RICEVIMENTO PREVIO APPUNTAMENTO VIA EMAIL O CHAT TEAMS / APPOINTMENT IS NEEDED, BY EMAIL OR TEAMS CHAT **D'ACQUISTO LEONARDO** Thursday 08:30 10:00 Edificio 8 - stanza docente

DOCENTE: Prof.ssa VALENTINA COSENTINO

PREREQUISITES	Knowledge of: physical quantities and measurement units; electric devices and circuits; measurement methods and instrumentation; measurement uncertainty; digital instrumentation.
LEARNING OUTCOMES	D.1: KNOWLEDGE AND UNDERSTANDING Students are expected to acquire knowledge and understanding basis concerning sensors for physical quantities monitoring and automatic measurement systems and for diagnosis, characterization and control of electrical and industrial systems, machines and processes. In detail a focus is made on sensing, signal conditioning equipment and systems based on data acquisition boards and PC-based instruments, signal acquisition and digital processing, virtual instruments programming. D.2: APPLYING KNOWLEDGE AND UNDERSTANDING Students are expected to apply their knowledge and understanding skills for the design and implementation of measurement chains, automatic measurement systems and PC-based instruments for diagnosis, characterization and control of electrical and industrial systems, machines and processes. The addressed aspects concern: sensors, signal conditioning and data acquisition equipment, with particular attention to the optimal choice of the metering equipment considering the specific application under study; data acquisition boards and instrumentation management by PC; virtual instrumentation design and development; time domain and frequency domain signal analysis. D.3: MAKING JUDGMENTS Students are expected to integrate their knowledge and increase their critical faculties for approaching problems and making judgements concerning the choice of the basic components of measurement chains, from sensors to signal conditioning and data acquisition equipment, and the design and development of automatic measurement systems and related software, starting from the available information, components technical specifications and requirements for the applications under study. D.4: COMMUNICATION SKILLS Students are expected to clearly communicate their knowledge, analysis and conclusions concerning the design, implementation and management of automatic measurement systems, the selection criteria of sensing and signal conditioning equipment and the measurements execution with data acquisition systems. In doing this, students are expected to address both specialist and non-specialist audiences, with correct use of language. D.5: LEARNING SKILLS Students are expected to develop methodological skills and abilities of connection and reworking of knowledge about proper selection and use of sensors for physical quantities, measurement chain equipment, automatic measurement systems and related interdisciplinary contexts. Thanks to this, students will be able to carry out further studies or professional activities with a high degree of autonomy, in those areas where knowledge and skills gained can be helpfully applied.
ASSESSMENT METHODS	EXAM OUTLINE The exam consists in a practical test and an oral exam. The practical test is based on the application of knowledge and skills gained in both course modules. it concerns the development of an automatic measurement system, based on data acquisition and processing of electrical signals and/or signals coming from sensors (at least one). The test includes: - the choice, sizing and setup of the measurement chain (sensors, signal conditioning equipment, data acquisition device or measurement instrument); - the development of the VI (software) for data acquisition system management and signal processing; the preparation of a written report on the developed project. During the exam, the student shall describe the developed work and discuss the choices and adopted solutions with the examination Board. The oral exam is a discussion with both open and semi-structured questions on both modules program. The practical test is aimed at evaluating: - knowledge, understanding and application of LabVIEW programming and fundamentals of sensing, signal conditioning, signals generation, acquisition and processing (analog and/or digital input/output);; - ability to describe and discuss the project choices and developed solutions. The oral exam is aimed at evaluating: - knowledge and understanding of the course programme; applying such skills for problem solving within the course or related contexts;

	- correct use of language, clearness, fluency; concepts reinterpretation, critical faculties, connection skills in disciplinary and/or interdisciplinary contexts. The mark is out of 30 and the minimum mark for passing the exam is 18/30. ASSESSMENT CRITERIA For each test, marks are awarded considering to what extent the student has achieved the learning outcomes. The following scheme can be assumed for reference (see learning outcomes section, descriptors D.1-D.5). Best fit applies when learning outcomes are met at different levels. 29-30 / 30 with distinction D.1/D.2: full contents mastery; no errors; self-corrections/integrations of inaccuracies/omissions; correct and rigorous approach to problems; correct, complete and effective solutions; some originality evidence D.3/D.4/D.5: effective concepts reworking, coherent and autonomous approaches and judgments, disciplinary/interdisciplinary connections; very clear presentation, structured arguments, correct use of language. 24-28 D.1/D.2: good/very good knowledge and understanding of course contents; few minor errors, partially fostered self-corrections or integrations; good approach to problems, essentially correct solutions; D.3/D.4/D.5: good coherence in linking concepts and approaching disciplinary or related subjects; good presentation, adequate use of language. 18-23 D.1/D.2: sufficient knowledge of contents; acceptable approach to problems although with limited autonomy, acceptable solutions; not serious errors or omissions; D.3/D.4/D.5: sufficient concepts links within disciplinary contexts, although tentative and guided; basic presentation and use of language. below 18 (exam failed) D.1-D.5: learning outcomes are not sufficiently met.
TEACHING METHODS	Lectures, classroom and laboratory exercises, projects/case studies development, analysis and classroom discussion. Teaching activities are organized to help the achievement learning outcomes (see learning outcomes section, descriptors D.1-D.5). The course contents are offered through lectures and guided exercises, emphasizing the applications and the synergy between the different topics (D.1). During the course, the contents are applied to problem solving issues and works on projects/case studies, thus stimulating the development of the ability to apply the acquired knowledge and skills (D.2). During lectures (partly carried out through dialogues and interactions among students and teacher), exercises and activities related to projects/case studies, students are fostered to critically analyze the proposed issues; this helps the development of students analytical abilities and autonomous judgment (D.3). At the same time, the dialogue and interaction opportunities foster students to improve their skills of communication, argumentation and use of language (D.4). Finally, all course activities contribute to the development of learning skills, through knowledge reworking, links to real and interdisciplinary applications and stimulus in facing new problems autonomously (D.5).

MODULE
SENSORS

Prof. LEONARDO D'ACQUISTO

SUGGESTED BIBLIOGRAPHY

- Doebelin, Ernest O. - “Strumenti e metodi di misura” “ II edizione – McGraw-Hill, 2008
- Dispense a cura del docente in formato pdf

AMBIT	20917-Attività formative affini o integrative
INDIVIDUAL STUDY (Hrs)	64
COURSE ACTIVITY (Hrs)	36

EDUCATIONAL OBJECTIVES OF THE MODULE

Actually, sensors and instruments are of immense importance in a wide variety of applications. The growth in the sophistication of instruments have been particularly significant, however little efforts are posed to the data validation, that is the full exploitation of inaccuracy associated to the collected data. Therefore, the aim of the course is to provide a solid foundation for the design of effective measuring systems for reaching valid experimental data of mechanical and thermal quantities in the main fields of industrial measurements.

SYLLABUS

Hrs	Frontal teaching
30	Sensors and transducers for mechanical and thermal measurements Motion , displacement and strain measurements - Relative linear and angular displacements: Resistive transducers - Differential transformers - Inductive and capacitive sensors - Synchro systems - Piezoelectric sensors - Electro-optical systems - Digital systems - Linear and angular relative speeds: Indirect measurement - Mechanical and electrical tachometers - Stroboscopes - Electromagnetic transducers - Seismic instruments for measurements of displacements, speeds and absolute accelerations - Strain measurement - Electric resistance strain gages. Electrical resistance. Sensitivity to deformation of the ER: sensitivity to axial and transverse strain, the K calibration factor , experimental determination of K. Linearity, temperature coefficient of the calibration factor. Sensitivity to temperature: apparent thermal strain, compensation by compensating ER and self-compensated ER, The resistance measuring circuit. The Wheatstone deviation bridge - strain gauge equation. Bridge supply systems. Types of connection: quarter bridge, half bridge, full bridge. Dynamic characteristics. - Measurements of mechanical forces and torques: primary conversion elements - Measurements of torques on rotating shafts. Strain gauge load cells - Pressure measurements: Primary conversion elements - Diaphragm pressure gauges - Electric vacuum gauges - Temperature measurements: Mechanical thermometers - Thermocouples - Resistance thermometers - Pyrometers. Use of Plank's law. Total irradiation pyrometers. Monochrome lamp pyrometers.

Hrs	Practice
6	Calibration procedures of measurement instrumentation for mechanical and thermal measurements

MODULE
AUTOMATIC MEASUREMENT SYSTEMS

Prof.ssa VALENTINA COSENTINO

SUGGESTED BIBLIOGRAPHY

Lecturer course slides (Dispense del corso fornite dal docente)
LabVIEW manual, available with software.
NI teaching material, tutorials, white papers, datasheets, scientific articles (chosen during the course for case studies analysis and practical exercises)

AMBIT	20917-Attività formative affini o integrative
INDIVIDUAL STUDY (Hrs)	80
COURSE ACTIVITY (Hrs)	45

EDUCATIONAL OBJECTIVES OF THE MODULE

The module aims at giving bases of automatic measurement systems and virtual instrumentation for monitoring, control and management of electrical systems, machines and processes in industrial applications.
For this purpose, the module educational objectives include the following knowledge and skills:
- knowledge of main types and features of automatic measurement systems and basic principles for their implementation and management, with particular respect to those based on PC and data acquisition boards;
- knowledge and understanding of main metrological issues related to data acquisition and signal processing.
- know-how to approach issues related to virtual instruments design and development, for signal analysis in both time and frequency domain and for management of data acquisition systems and measurement instrumentation by PC.

SYLLABUS

Hrs	Frontal teaching
12	Automatic Measurement Systems (AMS) generalities. AMS applications. AMS for physical quantities. AMS types, general principles, basic architecture. Measurement chain, AMS components. Data acquisition boards (DAQ). Types, features, technical specifications. Selection criteria. Use of analog and digital inputs/outputs (AIO-DIO). AMS based on PC and data acquisition boards (PC-based instruments). Signal acquisition and processing: metrological issues. Analog-to-digital (A/D) conversion. Signals sampling, quantization and coding. Analog-to-digital converters (ADC) types. ADCs features and technical specifications. Static and dynamic accuracy specifications. Quantization error, amplitude resolution (floor). Quantization error mitigation techniques. Sampling theorem, aliasing, anti-aliasing techniques. Harmonic analysis of digital signals. Observation window and frequency resolution. Synchronous and asynchronous sampling. Spectral leakage. Scallop loss and harmonic interference reduction techniques, window functions.
9	LabVIEW programming fundamentals. Programming environment. Windows, menus and tools. Front panel, block diagram, control palette, function palette, tool palette, status toolbar. Creating and using LabVIEW VIs. Block diagram code. Dataflow in LabVIEW programs. Main commands; data types, wirings, debug tools. Functions, Standard VIs, Express VIs. Programming structures. For loops; while loops. Arrays; clusters. Case and sequence structures. Shift register. Software timing in LabVIEW code. Code documentation. Modular programming. SubVIs. Front panel user interface. Controls, indicators, graphs. Waveform and express lib. File I/O functions, read and write data to files. DAQmx, DAQ Assistant. Control of measurement instrumentation through LabVIEW, instruments drivers.

Hrs	Practice
6	LabVIEW programming: basic exercises.

Hrs	Workshops
18	Virtual instruments development in LabVIEW environment for acquisition of signals coming from sensors and time and frequency domain signal analysis.DAQ AIO and DIO management. Examples of measurement instruments control with LabVIEW. Development and management of AMSs with data acquisition boards and PC-based instruments.