Module Code	EEU33C11
Module Name	Sensors
ECTS Weighting[1]	5 ECTS
Semester taught	Semester 2
Module Coordinator/s	Prof. Friedrich Wetterling
Module Learning Outcomes with reference to the Graduate Attributes and how they are developed in discipline	On successful completion of this module, students will be able to: LO 1: Apply the fundamentals of quasi-static electromagnetic field theory to the design of active and passive sensors including simulation and visualisation of electric and magnetic fields LO 2: Apply frequency domain characterisation methods to sensors LO 3: Specify requirements for sensor signal conditioning with respect to power resourcing, amplification, A/D conversion and filtering LO 4: Develop, specify, and critically review calibration and test methods for active and passive sensors LO 5: Critically evaluate aspects of sensor designs related to security, privacy, and society and select applicable design standards **Graduate Attributes: levels of attainment** To act responsibly - Enhanced To think independently - Enhanced To develop continuously - Enhanced To communicate effectively - Enhanced
Module Content	This module introduces sensor techniques and the signal conditioning electronics required to obtain useful information from sensors in both analogue and digital form. The module is particularly focussed on the use of sensors in practice in the MHz to GHz frequency range. Students obtain an understanding of sensor principles, capabilities and limitations. Objectives:

[1] TEP Glossary

- Understand the operation and limitations of various sensors/transducers system, and design suitable circuits to convert the analogue electric signals to digital data.
- Apply signal processing and calibration methods that relate the sensor data to useful information.
- Test the accuracy and precision of the sensor information in reference to gold standard measurements.
- Synchronise multiple measurements in time and apply signal processing techniques to the data.

Syllabus

1. Introduction to sensors
    a. sensor classification (passive / active, absolute / relative, changing quantity)
    b. sensing principle (biological, chemical, electromagnetic, heat/temperature etc)
    c. sensor metrics: linearity, noise, sensitivity, accuracy, resolution
    d. Examples: pressure sensor, light-based sensors, temperature sensors, magnetic field sensor
2. Electronic circuits and electromagnetism for sensors
    a. Resistors, Capacitors and Inductors
    b. Numerical modelling of magnetic fields created by electric circuits using Matlab
    c. Sensor characterisation using frequency response and transfer functions
    d. Example: the LC resonator and emerging sensors (MEMS, wearables etc)
3. Safety aspects for sensors
    a. Specific Absorption Rate (SAR)
    b. Electrical Safety
    c. Magnetic Safety
    d. Example: Sensors for Magnetic Resonance Imaging
4. Power Supply

a. Low power design

b. Energy harvesting

c. Digital to Analogue Conversion

d. radiofrequency transducers used for Magnetic Resonance Imaging (MRI) and piezo-electric transducers used for ultrasound

5. Signal Conditioning and filtering

   a. Need for Amplification, Filtering, Linearisation

   b. Converting resistance change to voltage / current changes

   c. Instrumentation amplifier, Schmitt trigger, Phased Locked Loop

   d. low-pass, bandpass, high pass-filtering

   e. Example: MEMS sensor signal conditioning chain

6. Sensor design

   a. Edge processing versus centralised processing

   b. Calibration

   c. Gold standard reference

   d. Medical Device standard - ISO 13485

   e. Medical Device Software standard - IEC 62304

   f. Testing, validation, and verification

7. Security, Privacy and Society

   a. Who owns the data?

   b. Implications for privacy, surveillance, AI considerations

   c. Sensors for the environment

Sustainable Development Goals Addressed
https://sdgs.un.org/goals

☐ No Poverty
☐ Zero Hunger
☒ Good Health and Well-Being
☐ Quality Education
☐ Gender Equality
☒ Clean Water and Sanitation
☒ Affordable and Clean Energy
☐ Decent Work and Economic Growth
☐ Industry, Innovation and Infrastructure

	☐ Reduced Inequalities ☒ Sustainable Cities and Communities ☐ Responsible Consumption and Production ☒ Climate Action ☐ Life Below Water ☐ Life On Land ☐ Peace, Justice and Strong Institutions ☐ Partnerships for the Goals
UNESCO Sustainable Development Key Competencies Covered **UNESCO Competencies Explained**	☐ Systems thinking ☒ Anticipatory ☐ Normative ☒ Strategic ☐ Collaboration ☐ Critical thinking ☒ Self-awareness ☒ Integrated problem-solving
Pedagogical Approaches Used **TCD Pedagogies**	☐ Critique ☐ Case base learning ☒ Experiential/ Practice based learning ☒ Problem based learning ☐ Project based learning ☒ Team based learning ☒ Fieldwork
Teaching and Learning Methods	This module will be taught via lectures and a laboratory

Assessment Details[2]
Please include the following:

- **Assessment Component**
- **Assessment description**
- **Learning Outcome(s) addressed**
- **% of total**
- **Assessment due date**

Assessment Component	Assessment Description	LO Addressed	% of total	Week due
Exam	In-person Exam	LO1-5	70	End of Semester
Labs	Report	LO4	20	[TBD]
Continuous assessment	Homework	LO1-3	10	

Reassessment Requirements

In-person Exam (70 %), Lab report (20%), and Homework (10%)

Contact Hours and Indicative Student Workload[2]

Contact hours: 30 hours
Independent study (preparation for course and review of materials): 60 hours
Independent study (preparation for assessment, incl. completion of assessment): 10 hours

Recommended Reading List

Dominik, Weishaupt; Victor D., Köchli; Brut, Marincek;"How does MRI work? An Introduction to the Physics and Function of Magnetic Resonance Imaging"

Griffith, David J.; "Introduction to electrodynamics"

Lonngren, Karl E.; Savov, Sava V.; Jost Randy J.; "Fundamentals of Electromagnetics with MATLAB, 2nd edition"

Mispelter, Jol; "NMR probeheads for biophysical and biomedical experiments: theoretical principles & practical guidelines"

Module Pre-requisite

EEU22E06 – Electronics or equivalent
PYU11E04 – Introduction to Electricity and Magnetism or equivalent

Module Co-requisite

None

Module Website	Blackboard
Are other Schools/Departments involved in the delivery of this module? If yes, please provide details.	No.
Module Approval Date	
Approved by	
Academic Start Year	Semester 2 2024/25
Academic Year of Date	2024/25