Course Syllabus

Course Information

Course Title: Smart Sensors in Industrial Instrumentation

Course Code: [To be assigned]

Level: Undergraduate / Graduate (adapt accordingly)

Credits: 3 ECTS (12 weeks × 1.5h lecture = 18 contact hours + independent work)

Prerequisites: Basic knowledge of electronics, instrumentation, and control systems

Course Description

This course introduces students to the design, operation, and application of smart sensors in industrial instrumentation. Starting from fundamental principles of measurement, students explore smart sensor architectures, signal conditioning, communication protocols, and advanced features such as self-calibration, sensor fusion, and edge intelligence. The course emphasizes industrial applications in process control, manufacturing, robotics, and IIoT, preparing students to integrate smart sensors in modern automation systems.

Learning Objectives

- Explain the operating principles of conventional and smart sensors.
- Analyze sensor performance parameters and calibration methods.
- Describe smart sensor architectures, communication protocols, and networking standards.
- Apply knowledge of MEMS, sensor fusion, and intelligent features in industrial contexts.
- Evaluate the role of smart sensors in process industries, robotics, predictive maintenance, and IIoT.
- Design and present a mini-project demonstrating smart sensor applications.

Weekly Schedule

Week 1 – Introduction

- Evolution from traditional to smart sensors
- Applications in automation and Industry 4.0
- Reading: Pallás-Areny & Webster, Sensors and Signal Conditioning (Introduction)
- Exercise: Classify sensors in an industrial plant (smart vs conventional).

Week 2 – Fundamentals of Sensors & Transducers

- Measurement principles: temperature, pressure, flow, displacement
- Sensor performance metrics
- Reading: Patranabis, Sensors and Transducers, Ch. 2–3
- Exercise: Plot calibration curves of example sensors.

Week 3 – Smart Sensor Architectures

- Anatomy: sensing element, signal conditioning, processing, communication
- IEEE 1451 Smart Transducer Interface
- Exercise: Block diagram design of a smart pressure sensor.

Week 4 – Signal Conditioning & Processing

- Analog vs digital conditioning
- Amplification, filtering, ADC/DAC
- Exercise: Design a low-pass filter for a noisy signal.

Week 5 – Communication & Networking

- Industrial protocols (I^2C, SPI, Modbus, CAN, HART, 4–20 mA)
- Wireless smart sensors (Zigbee, LoRa, Bluetooth, Wi-Fi)
- Exercise: Match protocols to application domains.

Week 6 – Calibration & Self-Diagnostics (Midterm Test)

- Calibration techniques (manual, automatic, cloud-based)
- Error detection and self-monitoring
- Assessment: Midterm exam (20%).

Week 7 – MEMS & Miniaturized Smart Sensors

- Basics of MEMS technology
- Examples: accelerometers, gyroscopes, microphones
- Exercise: Compare MEMS accelerometer vs conventional vibration sensor.

Week 8 – Intelligent Features in Sensors

- Embedded algorithms: averaging, compensation, redundancy
- Sensor fusion and edge computing
- Exercise: Design a redundant sensor system for fault tolerance.
- Project Proposal Due.

Week 9 – Applications I: Process Industries

- Smart pressure/temperature/flow transmitters
- Safety instrumented systems
- Case Study: Smart sensing in refineries.

Week 10 – Applications II: Manufacturing & Robotics

- Smart sensors in robotics (vision, force, proximity)
- Predictive maintenance with vibration and acoustic sensors
- Exercise: Propose predictive maintenance strategy for a motor.

Week 11 – Cyber-Physical Systems & IIoT

- Cloud integration, big data, AI for sensor data
- Cybersecurity challenges
- Exercise: Debate: Edge vs cloud data processing.
- Project Progress Presentation.

Week 12 – Future Trends & Presentations

- Nanotechnology, AI-enhanced sensors, biosensors
- Ethical and environmental concerns
- Assessment: Student project presentations (30%).

Assessment Methods

- Midterm Test (Week 6): 20%
- Mini-Project (proposal, progress, final presentation): 30%
- Final Exam: 50%

Suggested Mini-Projects

- IoT temperature and humidity logger with dashboard
- MEMS vibration monitoring for machine fault detection
- Smart pressure transmitter with simulated self-calibration
- Sensor fusion demo (accelerometer + gyroscope)

Recommended Textbooks

- Pallás-Areny, R., & Webster, J.G. Sensors and Signal Conditioning. Wiley.
- Patranabis, D. Sensors and Transducers. Prentice Hall.
- Beeby, S. MEMS Mechanical Sensors. Artech House.
- Bentley, J. Principles of Measurement Systems. Pearson.
- Selected journal papers and industry case studies (IEEE, Elsevier, ISA).

Learning Outcomes

- Identify and explain the role of smart sensors in industrial systems.
- Analyze, design, and evaluate smart sensor-based measurement solutions.
- Integrate smart sensors into control, monitoring, and IIoT applications.

- Communicate technical findings effectively through reports and presentations.