Advanced Intelligent Sensing Systems

Course Information

Course Number: PHYS 5V82
Term/Year/Duration: 2025 Fall/Winter
Course Title: Advanced Intelligent Sensing System

Instructor Information

Instructor Name: Prof. Hassan Askari
Email: haskari@brocku.ca
Office Locations: MCD 472

Instructor Name: Prof. Jasneet Kaur
Email: jkaur2@brocku.ca
Office Locations: MCE 220
Contact: 905 688 5550 X 3997

Teaching assistants: n/a

Times and Locations

Online, Self-directed

Course Calendar Description

By the end of this course, the student will gain a comprehensive understanding of Triboelectric Nanogenerators (TENGs), Piezoelectric Sensors, Embedded Circuits for Power Harvesting, Microcontrollers, and Machine Learning for Intelligent Sensing Systems.

Learning Outcomes:

- Understand and explain the fundamental working principles of Triboelectric Nanogenerators (TENGs) and Piezoelectric Sensors, including their materials, structures, and energy conversion mechanisms.
- Learn how to Design and analyze energy harvesting and power management circuits for self-powered sensing systems.
- To be able to Integrate TENGs, piezoelectric sensors, and embedded circuits with microcontrollers to build functional sensing prototypes.
- Understand and be able to apply wireless communication protocols and low-power microcontroller platforms for real-time data acquisition and transmission.
- Implement and evaluate machine learning algorithms (e.g., SVM, CNN, LSTM) to process and interpret data from self-powered sensors.
- To be able to develop a complete intelligent sensing system, demonstrating the integration of energy harvesting, signal processing, embedded control, and machine learning for a chosen application.

Required Readings or Texts

- Priya, S., & Inman, D. J. (Eds.). (2017), Energy Harvesting Technologies, Springer
- Barrett, S., & Pack, D. (2020), Embedded Systems: Design and Applications with the ARM Cortex-M Microcontrollers, Springer.
- Xichuan Zhou, Haijun Liu, Cong Shi, Ji Liu (2022) Deep Learning on Edge Computing Devices (Design Challenges of Algorithm and Architecture), Elsevier.
- Zhong lin Wang et al. (2023) Handbook of Triboelectric Nanogenerator.
- David Tse and Pramod Viswanath (2025), Fundamental of Wireless Communication, Cambridge University Press

Course Communications

Communications with instructors are conducted through weekly meetings.

Assessment Components and Due Dates

Table 1 Assessment Components

Assessment Component	**Grade**	**Due Date**
Provide monthly report during the scheduled meeting for the course	Will be assessed by the instructors. Covers 30 % of the mark Total 6 Presentations/Reports	On a monthly basis
Provide a detailed report in the form of a research article – Elsevier Template	70 % of the mark	End of Winter Semester
Total	Pass/Fail	

Task Descriptions

The task is based on weekly plan provided by the instructors. Student should provide a monthly report based on the planned content.

Late Submission Policy

The student should provide the monthly presentation/report and a final report/presentation of the comprehensive report by the end of Winter Semester. The late submission will result in mark deduction of 50% per report.

Important dates

The most recent listing of Important Dates for all durations is at https://brocku.ca/important-dates/all/

First day of classes: 3 September

Last day of Classes:

Last day of exams:

Deadline for withdrawal without academic penalty: 4 November

Relationship between attendance and grades:

Course attendance is on a weekly basis, and attendance will provide the opportunity for the student to present the work.

Academic Policies

Academic Integrity

Statement for undergraduate courses

Academic misconduct is a serious offence. The principle of academic integrity, particularly of doing one's own work, documenting properly (including use of quotation marks, appropriate paraphrasing and referencing/citation), collaborating appropriately, and avoiding misrepresentation, is a core principle in university study. Students should consult Section VII, "Academic Misconduct", in the "Academic Regulations and University Policies" entry in the Undergraduate Calendar to view a fuller description of prohibited actions, and the procedures and penalties. Information on what constitutes academic integrity is available at Brock University Academic Integrity Website.

Penalties for Academic Misconduct in the Faculty of Mathematics and Science

The following are penalties usually imposed in academic misconduct cases in FMS. Please be aware that the Associate Dean, Undergraduate Programs, may assign different penalties than those listed here, depending on the details of individual cases. When the offense involves misconduct on a final exam, the penalties are steeper.

Course work, including mid-term tests

First academic integrity offence: Zero grade on assignment, additional penalty of 100% of the weight of the assignment to be subtracted from the final grade, mandatory completion of the AZLS Academic Integrity workshop

Second academic integrity offence: Zero grade on assignment, zero grade in course OR 4-month suspension

Third or additional academic integrity offence: Zero grade in course, 1-year suspension, permanent removal from major program.

Final exams:

First academic integrity offence: Zero grade in course.

Second academic integrity offence: Zero grade in course, 4-month suspension

Third or additional academic integrity offence: Zero grade in course, 1-year suspension, permanent removal from major program.

Intellectual Property Notice

All slides, presentations, handouts, tests, exams, and other course materials created by the instructor in this course are the intellectual property of the instructor. A student who publicly posts or sells an instructor's work, without the instructor's express consent, may be charged with misconduct under Brock's Academic Integrity Policy and/or Code of Conduct, and may also face adverse legal consequences for infringement of intellectual property rights.

Accommodations

The University is committed to fostering an inclusive and supportive environment for all students and will adhere to the Human Rights principles that ensure respect for dignity, individualized accommodation, inclusion and full participation. The University provides a wide range of resources to assist students, as follows:

a) If you require academic accommodation because of a disability or an ongoing health or mental health condition, please contact Student Accessibility Services at askSAS@brocku.ca or 905 688 5550 ext. 3240.

b) If you require support with challenges related to health, well-being, and academic success, please feel free to visit Brock's Care and Connect webpage or contact studentaffairs@brocku.ca.

c) Medical Self-Declaration Forms (brief absence up to 72 hours)

In the case of a short-term medical circumstance, if a student wishes to seek an academic consideration, please use the Medical Self-Declaration Form. The request is to be made in good faith by the student requesting the academic consideration due to a short-term condition that impacts their academic activities (e.g., participation in academic classes, delay in assignments, etc.).

The period of this short-term medical condition for academic consideration must fall within a 72-hour (3 day) period. The form must be submitted to the instructor either during your brief absence or if you are too unwell, within 24 hours of the end of your 3-day brief absence.

Medical Verification Form (extended duration)
In cases where a student requests academic consideration due to a medical circumstance that exceeds 72 hours (three days) and will impact their academic activities (e.g., participation in academic classes, delay in assignments, etc.), or in the case of a final exam deferral, the medical verification form must be signed by the student and the health professional as per process set out in the Faculty Handbook III:9.4.1.

d) If you are experiencing mental health concerns, contact the Student Wellness and Accessibility Centre. *Good2Talk* is a service specifically for post-secondary students, available 24/7, 365 days a year, and provides anonymous assistance: Good 2 Talk or call **1-866-925-5454**. For information on wellness, coping and resiliency, visit: Brock University (Mental Health)

e) If you require academic accommodation on religious grounds, you should make a formal, written request to your instructor(s) for alternative dates and/or means of satisfying requirements. Such requests should be made during the first two weeks of any given academic term, or as soon as possible after a need for accommodation is known to exist.

f) If you have been affected by sexual violence, the Human Rights & Equity Office offers support, information, reasonable accommodations, and resources through the Sexual Violence Support & Education Coordinator. For information on sexual violence, visit Brock's Sexual Assault and Harassment Policy or contact the Sexual Violence Support & Response Coordinator at humanrights@brocku.ca or 905 688 5550 ext. 4387.

g) If you have experienced discrimination or harassment on any of the above grounds, including racial, gender or other forms of discrimination, contact the Human Rights and Equity Office at humanrights@brocku.ca.

Sequence and Dates of Topics and Readings

Course Outline

Week 1: Introduction to Intelligent Sensing Systems
Objective: Understand the role of intelligent sensing in modern applications.
Reading:
- Identify key references in the field
- Review papers on self-powered sensing and energy harvesting (e.g., from Advanced Materials, Nature Electronics).

Week 2: Fundamentals of Triboelectric Nanogenerators (TENGs)
Objective: Learn the working principles and types of TENGs.
Reading:
Working mechanism of TENG

Theory of TENG

Simulation of TENG

Material Selection of TENG for designing electrodes and dielectric platform

Week 3: Design and Fabrication of TENGs

Objective: Understand material selection and structural design for TENGs.
Reading:
- Materials and fabrication techniques in TENGs
- Experimental setups in TENG research papers

Week 4: Fundamentals of Piezoelectric Sensors
Objective: Learn the principles, materials, and applications of piezoelectric sensing.

- Compare TENGs and piezoelectric sensors in terms of efficiency and application scope.

Week 5: Signal Processing in TENGs and Piezoelectric Sensors
Objective: Understand how to process signals from nanogenerators and piezoelectric sensors.
Reading:
- Basic electronics for signal conditioning (Op-Amps, ADCs, filters).
- Papers on signal conditioning for energy harvesters
- Write a short report on common challenges in processing signals from self-powered sensors.

Week 6: Introduction to Embedded Circuits for Energy Harvesting
Objective: Learn about power management circuits for self-powered sensors.
Reading:
- Power conversion circuits
- Power Management for Energy Harvesting System.
Task:
- Design a simple circuit diagram for a power harvesting system.

Week 7: DC-DC Conversion and Power Management ICs
Objective: Learn how to store and regulate power from nanogenerators.
Reading:
- Papers on power management for nanogenerators.
- Datasheets of energy harvesting ICs (e.g., LTC3108, BQ25570).
Task:
- Select a power management IC and analyze its suitability for TENGs.

Week 8: Microcontrollers for Self-Powered Sensing Systems – Part I

Objective**:** Introduction to microcontrollers commonly used in energy-constrained sensing systems.
Reading:

- Arduino and ESP32 architecture basics
- GPIOs, ADCs, PWM, serial communication
- Power consumption and duty cycling techniques
  Task:

- Blink sensor data to serial output using an Arduino/ESP32.
- Measure power consumption in active vs. sleep mode using simple test code.

Week 9: Microcontrollers for Self-Powered Sensing Systems – Part II

Objective: Understand programming and real-time data acquisition from sensors.
Reading:

- Real-time task scheduling and interrupting
- Debouncing techniques for mechanical sensors
- Using low-power libraries (e.g., Low Power for Arduino)

Week 10: Advanced Microcontrollers and Processors – Part I

Objective: Introduction to advanced MCUs like ARM Cortex-M and TI MSP430.
Reading:

- ARM Cortex-M4/M33 and MSP430 datasheets
- Case studies of advanced MCU deployment in TENG projects

Week 11: Advanced Microcontrollers and Processors – Part II

Objective: Learn about real-time applications using advanced microcontrollers.
Reading:

- RTOS basics (e.g., FreeRTOS) for multitasking
- Low-energy features like DMA, watchdog timers, and event-driven wakeups

Week 12: Application Development with Advanced Microcontrollers – Part III

Objective: Complete an end-to-end microcontroller-based sensing system prototype.
Task:

- Build a project: Read sensor data → condition signal → apply data formatting → transmit via UART/SPI/I2C (Optional).
- Document the design decisions for low-power and performance trade-offs.

Week 13-15: Wireless Communication for Sensing Systems
Objective: Learn how to transmit data wirelessly in intelligent sensing systems.
Reading:
- Wireless sensor networks (IEEE Sensors Journal).
- Low-power communication protocols (BLE, LoRa, Zigbee).
Task:
- Prepare a detailed step-by-step report on how to implement wireless communication in a microcontroller setup using one of the low-power protocols.

Week 16-18: Case Studies on Self-Powered Intelligent Sensing Systems
Objective: Analyze real-world applications.
Reading:
- Case studies on self-powered biomedical, environmental, and industrial sensing.
- Papers on flexible and wearable sensing systems.

Week 19-20: Integration and System Design
Objective: Learn how to integrate TENGs, circuits, and microcontrollers into a complete system.
Reading:
- Review papers on system-level design of self-powered sensors.

Week 21-22: Machine Learning & Final Project
Objective: How to apply machine learning to process and analyze data from self-powered sensors.
Reading:
- Introduction to machine learning for IoT and sensor applications (IEEE Sensors Journal).
- Papers on ML for self-powered sensors (Nature Communications, Advanced Intelligent Systems).
- Basics of feature extraction and classification (e.g., SVM, CNN, LSTM for time-series data).

Week 23-24: Final Project Review & Presentation
Objective: Present and discuss the final report.
Reading:
- Review papers and project documentation.