

EE599 Fall 2017 Selected Topics

Energy Harvesting Circuits and Systems

Lecturer:

Dina El-Damak (eldamak@usc.edu)
PHE 620

Lectures:

Tuesday, Thursday, 9:30 am to 10:50 am, Location: TBD.

Office Hours (Tentative):

Monday, Wednesday, 3:00pm to 4:00pm, PHE 620.

Course Summary:

The advances in sensors, embedded processing, and wireless connectivity have fueled the emergence of wearable and implanted electronics. Rather than being carried in a pocket or a bag, these devices actually live on and in us and unobtrusively become part of our daily life. Since the users are always looking for seamless operation of this class of devices, which does not require their intervention to change or charge the battery, energy harvesting from the environment has emerged as a key solution for such systems. This course will provide the students with the solid foundation to design energy harvesting circuits for autonomous systems. The harvesting system consists of three main components (a) energy transducer that converts the energy from its free form in the environment into electrical energy, (b) interface circuits (power converters) that extract energy efficiently from the harvester and deliver it to the load, (c) control circuits for output voltage regulation, maximum power tracking, etc. Thus, the course will also be split into three modules as follows with extensive focus on the interface circuits design:

1. Power Converters Design: inductive based converters, switched capacitor DC-DC converters, rectifiers, passives, losses calculation and design strategies for maximal efficiency for ultra-low power applications.
2. ULP Control Circuits: circuit design in sub-threshold, maximum power extraction techniques, output regulation logic, design of ultra-low power reference circuits.
3. Fundamentals of Energy Transducers: equivalent circuits of energy transducers for solar, thermal and vibration based applications.

Prerequisite:

This course presumes an understanding of basic circuit theory and MOSFET device physics. The primary course prerequisite is EE348 (or an equivalent course).

Required Text Book:

The principle sources for this course will be class handouts and recent papers in the field of energy harvesting and power electronics. The following book is recommended for the first part of the course but not absolutely required: R. W. Erickson and D. Maksimovic, Fundamentals of Power Electronics, Second edition, Kluwer, 2001.

Preliminary Course Outline:

- Week 1: Introduction to self-powered systems and energy harvesting circuits.

Part 1: Power Converters Design

- Week 2: Principles of steady state converter analysis.
- Week 3: Inductive-based converters - continuous conduction mode.
- Week 4: Inductive-based converters - discontinuous conduction mode.
- Week 5: Switched capacitor DC-DC converters design.
- Week 6: Rectifier design, energy methods for calculating losses.
- Week 7: Passives. ***Class project announced.***

Part 2: ULP Control Circuits

- Week 8: MOSEFT in subthreshold - device physics review.
- Week 9: Maximum power extraction techniques, startup circuits.
- Week 10: Pulse frequency modulation and techniques for activity and leakage reduction.
- Week 11: ULP voltage reference and current reference circuits.

Part 3: Fundamentals of Energy Transducers

- Week 12: Equivalent circuits of energy transducers (Part 1).
- Week 13: Equivalent circuits of energy transducers (Part 2).
- Week 14: System examples.
- Week 15: Project discussion.

Tentative Grading Plan:

The grading will be based on four components:

- Homework (35%)
- Midterm Exam (30%)
- Project (30%)
- Class Participation (5%)

The project involves the design and simulation of electronic circuits using IC design tools. The students are encouraged to work in teams of 2, and it will be graded based on a final report submitted during the last week of the classes.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" <https://policy.usc.edu/scampus-part-b/>. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, <http://policy.usc.edu/scientific-misconduct>.

Support Systems:

Student Counseling Services (SCS) - (213) 740-7711 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

<https://engemannshc.usc.edu/counseling/>

National Suicide Prevention Lifeline - 1-800-273-8255

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. <http://www.suicidepreventionlifeline.org>

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 - 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender-based harm. <https://engemannshc.usc.edu/rsvp/>

Sexual Assault Resource Center

For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: <http://sarc.usc.edu/>

Office of Equity and Diversity (OED)/Title IX compliance – (213) 740-5086

Works with faculty, staff, visitors, applicants, and students around issues of protected class. <https://equity.usc.edu/>

Bias Assessment Response and Support

Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. <https://studentaffairs.usc.edu/bias-assessment-response-support/>

The Office of Disability Services and Programs

Provides certification for students with disabilities and helps arrange relevant accommodations. <http://dsp.usc.edu>

Student Support and Advocacy – (213) 821-4710

Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. <https://studentaffairs.usc.edu/ssa/>

Diversity at USC

Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. <https://diversity.usc.edu/>

USC Emergency Information

Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible, <http://emergency.usc.edu>

USC Department of Public Safety – 213-740-4321 (UPC) and 323-442-1000 (HSC) for 24-hour emergency assistance or to report a crime

Provides overall safety to USC community. <http://dps.usc.edu>