# EEC 216 - Low Power Digital Integrated Circuit Design

**Lecture:** MW 9-10:30
Wellman 5

**Instructor:** Rajeevan Amirtharajah
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**Web Page:** Access course webpage through UC Davis SmartSite.

**Office Hours:** M 10:30-11:30

**Prerequisites:** EEC 118

**Grading:** Letter (A: 100-90%, B: 90-80%, C: 80-70%, D: 70-60%, F: below 60%)
Midterm 30%
Homework 5%
Design Project #1 15%
Design Project #2 20%
Final Project 30%

There will be a few homework assignments, two design projects, one midterm exam, and one final project. The midterm exam will be held in class on Wednesday 2/19. Final project presentations will occur during the final exam period. Homework problems will be graded on an effort scale: 0 points for poor effort, 1 point for nearly correct/reasonable effort, and 2 points for a correct answer.

**Collaboration:** You may discuss issues with other students on design projects, but you must design your own circuit and circuit test bench and perform your own simulations. Each student must turn in their own circuit design and project writeup. If you choose to discuss the project with other students, each student must list all of his/her colleagues who participated in any discussion(s) on the first page of their homework. Final projects will be done individually or in groups of at most two.

**Late Design Projects:** Design projects are due at the beginning of lecture. Twenty-five percent of the total points are deducted for each day the homework is late, until the assignment is worth 0 points four days after the official due date.

**Curves:** No curves on design projects. Exams will be graded on a curve if the class performance warrants it, and the curve will only improve your grade.

**Extra Credit:** No individual extra credit. Instructor might offer an extra credit assignment to the entire class, but only if absolutely necessary.

**Course Description:** IC design for low power and energy consumption. Low power architectures, logic styles, and circuit design. Variable supply and threshold voltages. Leakage management. Power estimation. Energy sources, power electronics, and energy recovery. Applications in portable electronics and sensors. Thermodynamic limits.

**Course Outline:**

I. Overview of Low Power Design

   A. CMOS Power Dissipation
   B. Power and Performance Tradeoffs
   C. Trends in IC Power Consumption

II. Low Power Circuit Design

   A. Logic Power Estimation
   B. Leakage Power and Multi-Gate FETs
   C. Power Minimization in Static CMOS
   D. Power Minimization in Dynamic CMOS
   E. Multiple-Threshold CMOS
   F. Variable Supply and Threshold Voltages
   G. Managing Leakage
   H. Subthreshold Circuit Design
   I. Silicon-on-Insulator (SOI) Technologies
   J. Interconnect Power Estimation and Management

III. Low Power Architectures

   A. Clock Gating and Clock Management
   B. Pipelining to Reduce Supply Voltage
   C. Parallelization to Reduce Supply Voltage

IV. Energy Sources and Power Electronics

   A. Batteries and Fuel Cells
   B. Energy Scavenging
   C. DC/DC Converters: Fundamentals
   D. DC/DC Converters: Optimization

V. Other Topics in Low Power Design

   A. Low Power Synthesis

B. Energy Recovery

C. Applications: Computing, Communication, and Multimedia

D. Applications: Sensors and Sensor Networks

E. Fundamental Limits and Thermodynamics of Computation

**Reading:**

1. Most material will be from classic and recent research papers on low power design.

**Reference Material:**

1. Roy, K. and Prasad, S., *Low Power CMOS VLSI: Circuit Design*.
2. Chandrakasan, A. and Broderson, R., eds., *Low-Power CMOS Design*.
3. Chandrakasan, A. and Broderson, R., *Low Power Digital CMOS Design*.
4. Rabaey, J., Chandrakasan, A., and Nikolic, B., *Digital Integrated Circuits: A Design Perspective*, 2nd ed.
5. Kassakian, J., Schlecht, M., and Verghese, G., *Principles of Power Electronics*.

| Lecture | Date | Title |
|---|---|---|
| 1 | 01/06/14 | CMOS Power Dissipation and Trends |
| 2 | 01/08/14 | Metrics and Logic Level Power Estimation |
| 3 | 01/13/14 | Leakage and Multi-Gate FETs |
| 4 | 01/15/14 | Low Power Circuits 1 |
| | 01/20/14 | Martin Luther King, Jr. Day |
| 5 | 01/22/14 | Low Power Circuits 2<br>Sizing for Low Power |
| 6 | 01/27/14 | Clocking and Sequential Circuits |
| | 01/29/14 | Alternative Latch Styles and Self-Timed Design |
| 7 | 02/03/14 | Circuit Techniques for High Leakage |
| | 02/05/14 | Subthreshold Circuit Design |
| 8 | 02/10/14 | Low Power Interconnect 1 |
| | 02/12/14 | Low Power Interconnect 2 |
| | 02/17/14 | President's Day |
| | 02/19/14 | Midterm |
| 9 | 02/24/14 | High Level Power Estimation<br>Interconnect Power |
| 10 | 02/26/14 | Clock Gating and Power Down Modes<br>Pipelining and Parallelization |
| 11 | 03/03/14 | Batteries, Fuel Cells, and Power<br>MEMS |
| 12 | 03/05/14 | Energy Scavenging |
| 13 | 03/10/14 | DC/DC Conversion 1 |
| | 03/10/14 | DC/DC Conversion 2 |
| 14 | 03/12/14 | Energy Recovery Techniques |
| 15 | 03/17/14 | Thermal Design<br>Temperature Measurement Circuits |
| 16 | Optional | Low Power CMOS Applications:<br>Ultra Low Power Sensor DSP |
| 17 | Optional | Fundamental Limits and Thermodynamics of Computation |
| | 03/22/14 | Final Project Presentations |