Instructor: Maysam Ghovanloo, Ph.D. (mghovan@ncsu.edu), 445 MRC Building, Phone: (919) 513-1923
Office Hours: Mondays 2:00-4:00pm, other times with prior appointment

TA: Suresh Atluri (satluri@unity.ncsu.edu), Location?
Office Hours: Wednesdays 2:00-4:00pm

Textbook: CMOS Circuit Design, Layout, and Simulation
(Required)
R. Jacob Baker
IEEE Press, ISBN: 047170055, $72.30 (new), $64.50 (used)
Will be referred to as: Baker

Other References:
1. Analysis and Design of Analog Integrated Circuits
   P.R. Gray, P.J. Hurst, S.H. Lewis, R.G. Meyer
2. Design of Analog CMOS Integrated Circuits
   B. Razavi
3. CMOS Analog Circuit Design
   P.E. Allen, D.R. Holberg
4. The Art of Analog Layout
   A. Hastings
5. Medical Instrumentation: Application and Design
   J.G. Webster (Editor)

Prerequisites: ECE-711 and ECE-403 or equivalents.

It is assumed that the students are familiar with the following topics:

1. Solid-state device operation and circuits: P-type and N-type semiconductors, diodes, bipolar junction transistors, and MOS field-effect transistors. Small signal models and their associated parameters as well as their primary parasitic components.

2. Transistor level design of amplifiers, including active loads, biasing, frequency response, settling time, offset, feedback, and stability. A basic knowledge of the operational amplifier topology and functions.

3. Basic communications system theory, including modulation techniques, such as AM, FM, and PM.

4. Using one of the available CAD tools such as HSPICE and Cadence for circuit schematic entry, simulation, and layout design.
Course Description:

The U.S. federal estimates predict that health care spending will surpass $2 trillion in the next decade. Within the health care technology, biomedical devices represent one of the fastest growing segments. On the other hand, analog and mixed-signal integrated circuits play a significant role in design of biomedical devices, due to the analog nature of the biological systems. Detailed discussion of circuit blocks such as voltage and current references, current sources and current sinks, amplifiers, regulators, filters, A to D, and D to A converters, as well as low-power, low-noise, and wireless circuit techniques will be covered with emphasis on the biomedical applications of these circuits in biopotential amplifiers, bio-sensor interface circuits, microstimulators, and signal conditioning blocks. These circuits, however, can be applied to a wide variety of other applications. This is a research/project oriented course and the final project, presentation, and report comprise a significant part of the final grade. Students are also expected to have an active role in the class discussions.

Course Project:

Groups of 2 or 3 students choose a topic on applications of the aforementioned circuit blocks in biomedical engineering, consult with the instructor or other faculty, and propose their project topic in a 1-page draft (Draft-1) by the end of September. After receiving approval from the instructor, group members perform a thorough literature survey on their selected topic, and come up with a circuit design idea for that specific biomedical application.

A summary of the literature survey, system block diagram, and selected circuit topologies should be included in a 2nd draft (Draft-2), and turned in by the end of October. These circuit designs should target one of the two available standard CMOS processes: AMI-1.5µm or AMI-0.5µm. Detailed information about these processes and transistor models are available through MOSIS website (www.mosis.org). The instructor will provide each group with feedback on Draft-2.

Considering the significance of IC layout in the performance of analog circuits, important layout design techniques that affect the circuit performance in terms of matching, minimizing parasitic components, and linearity, will be covered in class. Starting this semester, all or part of the proposed circuit should be laid out, following the layout design techniques. Part of the project grade is dedicated to circuit layout, its technical features, and post layout simulations.

Finally the complete design, including a summary of the literature survey, design calculations, complete circuit schematics, circuit layout, post-layout simulation waveforms, and circuit characterization results will be turned in by the end of the semester in a paper that should follow the IEEE journal format. Links to the IEEE general information for authors is provided on the course webpage. There, you can also find template files for Word and LaTeX.

Towards the end of the semester, each group should present the entire project in a 20-min slide presentation (15-20 slides) for the rest of the class in a conference style. These sessions will be open to public audience. Other faculty members and experts from industry might be invited to evaluate the projects. The entire group should participate in the presentation and will be asked questions for 5-min by the instructor and other audience after the 20-min presentation. To assess the individual participation of the group members, students will periodically be asked to fill out individual effort assessment forms about their group members.

Those groups with functional circuit designs, based on post-layout simulations, will be given a chance to submit their IC layouts for fabrication. According to the MOSIS schedule, the final
tape-out deadlines for AMI-1.5µm and AMI-0.5µm processes are Nov. 28\textsuperscript{th} and Nov. 14\textsuperscript{th}, 2005 respectively. Group members are encouraged to test and characterize their ICs after fabrication. Functional devices will be considered for additional experiments in their particular biomedical applications. If successful, measurement and experiment results will be considered for submission to national professional meetings.

**Reading Assignments:**

Reading assignments include sections of the textbook, supplementary notes, on-line articles, and several conference/journal papers that are relevant to the course topics. Supplementary notes will also be handed out during lectures, which topics are not included in the textbook. Students are responsible for both lecture material and reading assignments for the midterm, project, and final examination.

**Homework:**

Four to six problem sets will be issued on Thursdays and they will be due at the beginning of class on the following Thursday. There will occasionally be assignments for which two weeks will be allocated. These assignments are also due at the beginning of Thursday classes. The lowest homework grade will count half as much as the others, and *No late homework will be accepted.*

**Midterm Exam:**

A midterm exam will be held sometime between mid-October and mid-November in one of the class sessions. The exact date will be indicated by the end of September.

**Final Exam:**

The final exam will take place during the examination period as indicated in the Fall-2005 Examination Schedule (Tuesday, Dec. 13\textsuperscript{th} 1pm to 4pm). This examination will cover all of the material in the course including lectures, problem sets, and reading assignments.

**Missed Exam:**

If you miss midterm exam or do not attend your presentation without a certified medical excuse or prior instructor approval, a zero will be averaged into your grade. Certified excuses and prior approval will be dealt with individually. Generally, the missed exams will be held at a designated time near the end of the semester and before the final exams. This means that there will be only one make-up test, independently from which exam/presentation you miss. Thus, the make-up test will be comprehensive. To request an excused absence, 1- write a formal letter to the instructor (typeset), dated and signed, stating your specific request and the reason you are asking for an excused absence; 2- provide documentation supporting your request; 3- bring this letter and the documentation to the instructor in person before the requested date (if an absence is foreseeable) or within one week after the absence (if it is of unforeseeable nature), at which time your request will be discussed. Special cases will be dealt individually. To see the official academic policies regarding missed exams: [http://www.ncsu.edu/policies/academic_affairs/pols_regs/REG205.00.4.php](http://www.ncsu.edu/policies/academic_affairs/pols_regs/REG205.00.4.php)

**Academic Integrity:**

Please refer to the NCSU policy on academic integrity found in the code of student conduct (*Appendix L of the Handbook for Advising and Teaching*). It is the instructor’s understanding
that the student’s signature on any test or assignment means that the student neither gave nor received unauthorized aid. All provisions of the university *Code of Student Conduct* apply to this course. Please familiarize yourself with university policies on academic integrity by visiting: [http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php](http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php)

**Disabilities:**

Reasonable accommodations will be made for students with verifiable disabilities. To qualify for these accommodations, students must register with Disability Services at 1900 Student Health Center, Campus Box 7509, 515-7653 ([http://www.ncsu.edu/provost/offices/affirm_action/dss/](http://www.ncsu.edu/provost/offices/affirm_action/dss/)). For more information: [http://www.ncsu.edu/provost/hat/current/appendix/appen_k.html](http://www.ncsu.edu/provost/hat/current/appendix/appen_k.html)

**Grading Policy:**

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>15%</td>
</tr>
<tr>
<td>Midterm</td>
<td>15%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>30%</td>
</tr>
<tr>
<td>Project</td>
<td>40%</td>
</tr>
<tr>
<td>1st Draft</td>
<td>5%</td>
</tr>
<tr>
<td>2nd Draft</td>
<td>10%</td>
</tr>
<tr>
<td>Layout and simulations</td>
<td>30%</td>
</tr>
<tr>
<td>Presentation</td>
<td>20%</td>
</tr>
<tr>
<td>Final Paper</td>
<td>30%</td>
</tr>
<tr>
<td>Group cooperation</td>
<td>5%</td>
</tr>
</tbody>
</table>

A- / A+: 90.0 – 100.0  
B- / B+: 80.0 – 89.9  
C- / C+: 70.0 – 79.9  
D- / D+: 60.0 – 69.9  
F: 0.0 – 59.9  

The exact grade (e.g. A-, A, A+) within the specified ranges will vary according to your overall performance, teamwork, design novelty, and active participation in class. Absolute grading system will be applied (no curving). Therefore, your performance depends only on how you and your team do, not on how everyone else in the class does.

**Auditing Criteria:**

To Audit ECE-703 you will need to:

1. Attend all sessions
2. Do the project (it would be better if you form a group with other students who are auditing the course)
3. Final presentation
4. Final report

Basically you just do not need to turn in homework or participate in any of the exams. Everything else would be the same as taking the course for credit.

**Course Topics and Schedule (Tentative):**

- Introduction (8/18/05)
- Review of structures and models of the active IC devices
- Current sources and current sinks
- Microstimulators and pacemakers
• Reference generators and regulators
• Amplifiers and output stages
• Inductive coupling and wireless power transmission
• Differential, operational, and instrumentation amplifiers
• Comparators, level shifters, and mixers
• Biopotential recording and sensor signal conditioning
• Data converter circuits
• Switch-capacitor circuits

<table>
<thead>
<tr>
<th>Exam/Project</th>
<th>Due Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>First draft</td>
<td>9/29/05</td>
<td>5:00 pm</td>
</tr>
<tr>
<td>Second draft</td>
<td>10/27/05</td>
<td>5:00 pm</td>
</tr>
<tr>
<td>Midterm exam</td>
<td>11/1/05</td>
<td>In class</td>
</tr>
<tr>
<td>Tape-out to MOSIS</td>
<td>11/14/05 and 11/28/05</td>
<td>9:00 am</td>
</tr>
<tr>
<td>Presentations</td>
<td>11/29/05 and 12/1/05</td>
<td>In class</td>
</tr>
<tr>
<td>Final paper</td>
<td>12/6/05</td>
<td>5:00 pm</td>
</tr>
<tr>
<td>Final exam</td>
<td>12/13/05</td>
<td>1:00-4:00 pm</td>
</tr>
</tbody>
</table>