1 INSTRUCTIONAL SUPPORT

1.1 Instructor
Instructor: Stefano Gregori
Office: RICH 3521, ext. 56191
Email: sgregori@uoguelph.ca
Office hours: posted on the course webpage or by appointment

1.2 Laboratory technician
Technician: Joel Best
Office: RICH 3501, ext. 54234
Email: jbest@uoguelph.ca

2 LEARNING RESOURCES

2.1 Course website
Information and materials will be posted in the course web page on CourseLink.

2.2 Required resources
Textbook:


2.3 Recommended resources
Reference books on analog design:


**Reference books on selected advanced topics:**


**Reference journals:**

• *Analog Integrated Circuits and Signal Processing*, ISSN 09251030.

• *IEEE Journal of Solid-State Circuits*, ISSN 00189200.

• *IEEE Transactions on Circuits and Systems, Part I and II*, ISSN 10577122 and 10577130.

• *Electronics Letters*, ISSN 00135194.

• *Microelectronics Journal*, ISSN 00262692.

The books above are available on Course Reserve in the library. Additional references are indexed by library call numbers TK7800 to TK8360.

The journal articles are available through [http://ja.lib.uoguelph.ca/](http://ja.lib.uoguelph.ca/)

### 2.4 Additional resources

**Lecture information:** Handouts will be provided in class and reading materials will be posted on the course web page.

**Laboratory information:** Laboratory instructions will be provided in class, while manuals and reference materials will be available through the course web page.

**Midterm exams:** More information related to the midterm exams will be given two weeks in advance.

### 2.5 Communication and email policy

Communication is through announcements in class. Some information will be posted on the course web page or sent via email messages to your University address. It is your responsibility to keep yourself informed about the course. As per University regulations, you are expected to check regularly your University email account on [https://mail.uoguelph.ca](https://mail.uoguelph.ca), because email is the official route of communication between the University and its students.
3 ASSESSMENT

3.1 Dates and distribution

Laboratories: 42% (i.e. three assignments worth 14% each)
   Please see section 5.3 for schedule and due dates.

Project: 30%
   Please see section 5.3 for schedule and due date.

Midterm exam 1: 14%
   Thursday, 13 February 2014, 14:30 to 15:30, in RICH 2531.

Midterm exam 2: 14%
   Thursday, 13 March 2014, 14:30 to 15:30, in RICH 2531.

3.2 Course grading policies

Failure to complete a course requirement: If you are unable to meet an in-course requirement because of illness or compassionate reasons, please advise the course instructor in writing at the earliest possible time. Please see the Graduate Calendar for information on academic consideration: http://www.uoguelph.ca/registrar/calendars/graduate/2013-2014/genreg/sec_d0e1415.shtml

Accommodation of religious obligations: If you are unable to meet an in-course requirement due to religious obligations, please email the course instructor within two weeks of the start of the semester or at the earliest possible time.

Passing grade: The passing grade is 65%.

Missed exams: Any student not taking an exam receives a grade of zero for that exam. In case you have a legitimate reason for missing an exam session, the instructor may consider an accommodation upon presentation of a written request and suitable documentation before the time of the exam.

Laboratory work: You must attend and complete all laboratories. In case you have a legitimate reason for missing a laboratory session, the instructor may consider an accommodation upon presentation of a written request and suitable documentation before the time of the laboratory.

Late laboratory and project reports: Any student not handing in a report receives a grade of zero for that submission. There are no makeup reports and late submissions are not accepted for marking.

Copies of reports: Please keep back-up copies of all out-of-class assignments (i.e. laboratory and project materials), because you may be asked to resubmit your work.

Questions about grades: If you have questions about the grade your submission received, please ask the instructor within two weeks after the document has been returned.
4 AIMS, OBJECTIVES, AND GRADUATE ATTRIBUTES

4.1 Calendar description

In this course, operating principles and design techniques of analog integrated circuits are introduced with emphasis on device and system modelling. These circuits include analog and switched-capacitor filters, data converters, amplifiers, oscillators, modulators, circuits for communications, sensor readout channels, and circuits for integrated memories.

4.2 Course aims

The subject of this course is the analysis and design of analog integrated circuits (ICs) in complementary metal-oxide-semiconductor (CMOS) technology.

Why analog?

- Amplification: Analog circuits can amplify weak signals from antennas and sensors and can drive actuators and displays with the right levels. Digital circuits can only handle rail-to-rail signals.
- Performance: Analog circuits are faster and more accurate than digital circuits. High-speed digital circuits and high-density digital memories are analog circuits designed to produce discrete states.
- Power: Analog circuits implement power management and conversion functions and ultra low power systems. They improve power efficiency through voltage scaling and energy scavenging.
- Mixed signal: Mixed-mode systems with both analog and digital circuits are widespread. Understanding analog circuits is crucial for designing complex electronic systems.

Why CMOS?

- Integration density: CMOS is the only fabrication technology that can integrate billions of elements on a single microchip.
- Power: The power consumption of analog CMOS circuits can be lowered to nanowatts. The power consumption of digital CMOS circuits is very low as well.
- Performance: CMOS implementations have extremely high input impedance, can handle a wide range of voltages, and achieve excellent performance in most designs.
- Reliability and cost: CMOS is the most developed and used IC technology. It achieves high yields at low manufacturing costs.

As microsystems integrate more elements in a smaller area, analog circuits are becoming more significant and sophisticated, because they provide the indispensable interface between digital computers and signal processing, acquisition, communication, and storage functions. Therefore competence in the analysis and design of analog ICs is a key requirement for designers in areas like cellular communication, audio, imaging, high-speed, interface, clocking, medical, high-volume linear, automotive, storage, power supply, battery management, linear power, and more.
This course examines the circuit techniques and the technology aspects associated with ICs and the challenges that lie ahead in their development. Modelling techniques are used to gain a better understanding of circuit functions. Intuitive design methods, quantitative performance assessments, and practical circuit limitations are emphasized. Circuit behaviour and design trade-offs are predicted by intuition and simple hand calculations, and then verified by computer simulations. The goal is to achieve a good understanding of the driving and limiting factors in circuit performance, of the design tools, and of the technology issues in analog IC design.

4.3 Learning objectives

After successfully completing the course you will be able to describe operating principles and performance characteristics of analog ICs and to apply the studied concepts to the design of complex systems. To this purpose you will learn to:

1. Understand and apply MOS transistor large-signal and small-signal device models.
2. Grasp the importance of circuit structures, physical and technological parameters, layout construction, and device modelling.
3. Calculate large-signal and small-signal characteristics of single-stage amplifiers and current mirrors.
4. Analyze, simulate, and synthesize differential amplifiers, multi-stage circuits, and feedback configurations.
5. Read technological parameters, design specifications, circuit schematic and layout diagrams in order to estimate performance and to identify critical elements.
6. Apply Cadence computer-aided design and simulation tools to build, improve, and verify analog IC blocks and systems.
7. Design an assigned circuit to a set of specifications and test it with simulations.
8. Communicate effectively about specifications, design, simulation, testing, and applications of analog ICs.

4.4 Graduate learning outcomes

Successfully completing this course will contribute to the following University of Guelph learning outcomes for graduate degrees:

**Critical and creative thinking:** Lectures and assignments deal with the application of circuit analysis, modelling concepts, and control theory to IC operation. Design projects challenge the students to identify issues and formulate their individual solutions. Students demonstrate creativity and innovation in the application of knowledge to the analysis and solution of circuit problems. They make and justify IC design decisions on the basis of acquired knowledge and analysis.

**Literacy:** Lectures and assignments discuss design methods, technological parameters, and circuit schematic and layout diagrams. Information from books, scientific journals, technical standards, and device data-sheets is introduced. Laboratory sessions include computer-aided design tools and related documentation. Students identify reliable information, select appropriate methods to undertake their assignments, and configure and apply test conditions to evaluate outcomes.
Global understanding: Course activities reinforce awareness of the limits of knowledge and of the steps to follow to increase knowledge. Lectures emphasize how IC solutions are based on principles of physics and mathematics and how IC technology has global economic, social, and environmental impact. Student apply modelling and design skills to realistic problems and consider ranges of applicability, limitations, and potential consequences.

Communicating: Course activities include giving and responding to instructions and inquiries, understanding and producing technical documentation, and giving and attending to presentations. Lectures emphasize how comprehending and communicating effectively complex IC concepts involve the acquisition of technical communication skills and terminology. Students receive and convey engineering concepts clearly and consistently by oral, written, and graphical means.

Professional and ethical behaviour: Throughout the course students are encouraged to ethical behaviour consistent with academic integrity and professional ethics and accountability. Students keep a high level of honour in their work and understand the importance of including the public good as a goal in engineering activities, even if this requirement is not explicitly articulated.

4.5 Instructor’s role and responsibility to students

The instructor’s role is to develop and deliver course material in ways that facilitate learning for a variety of students. The lecture notes and materials available to students on the course web site are not intended to be a stand-alone course. During the lectures, the instructor expands and explains the course contents and provides example problems that supplement notes and textbook. Scheduled classes and laboratory sessions are the principal venue to provide information and feedback about exams and laboratories.

4.6 Students’ learning responsibilities

Students are encouraged to take advantage of all the learning opportunities provided by lectures and laboratory sessions. Students, especially those having difficulty with the course content, should also make use of additional resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This allows the instructor to recommend extra resources in a timely manner and provide consideration if appropriate.

4.7 Relationships with other courses

Success in this course requires a good understanding of the following elements:

- Mathematical tools for describing continuous-time systems (including integral transforms and Bode plots).
- Techniques for electric circuit analysis (including the dynamics of linear circuits in transient and at low and high frequency).
- Fundamentals of electronics (including semiconductor device operation and simple MOS amplifier circuits).

This material is roughly covered by undergraduate courses equivalent to ENGG*2450 and ENGG*3450.
5  Teaching and Learning Activities

5.1 Timetable

Lectures:

Thursday, 14:30 to 17:30, in RICH 2531

Laboratory sessions:

Tuesday, 14:30 to 17:30, in RICH 2531

5.2 Lecture schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Lecture topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jan-06 to Jan-10</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Jan-13 to Jan-17</td>
<td>Electronic systems</td>
</tr>
<tr>
<td>3</td>
<td>Jan-20 to Jan-24</td>
<td>MOS transistor</td>
</tr>
<tr>
<td>4</td>
<td>Jan-27 to Jan-31</td>
<td>Passive elements</td>
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<tr>
<td>5</td>
<td>Feb-03 to Feb-07</td>
<td>CMOS fabrication</td>
</tr>
<tr>
<td>6</td>
<td>Feb-10 to Feb-14</td>
<td>Analog building blocks</td>
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<tr>
<td>7</td>
<td>Feb-17 to Feb-21</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>Feb-24 to Feb-28</td>
<td>Analog building blocks</td>
</tr>
<tr>
<td>9</td>
<td>Mar-03 to Mar-07</td>
<td>Voltage and current sources</td>
</tr>
<tr>
<td>10</td>
<td>Mar-10 to Mar-14</td>
<td>Advanced topics</td>
</tr>
<tr>
<td>11</td>
<td>Mar-17 to Mar-21</td>
<td>Advanced topics</td>
</tr>
<tr>
<td>12</td>
<td>Mar-24 to Mar-28</td>
<td>Review</td>
</tr>
<tr>
<td>13</td>
<td>Mar-31 to Apr-04</td>
<td>Review</td>
</tr>
</tbody>
</table>

Topics schedule will be adjusted throughout the course as needed.

5.3 Laboratory schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Topics</th>
<th>Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jan-06 to Jan-10</td>
<td>Introduction to design tools and laboratory safety</td>
<td>—</td>
</tr>
<tr>
<td>2, 3</td>
<td>Jan-13 to Jan-24</td>
<td>Device characteristics, sweep and transient analysis</td>
<td>Jan-24</td>
</tr>
<tr>
<td>4, 5</td>
<td>Jan-27 to Feb-07</td>
<td>Analog building cells and design flow</td>
<td>Feb-07</td>
</tr>
<tr>
<td>6, 7</td>
<td>Feb-10 to Feb-28</td>
<td>Analog blocks and design flow</td>
<td>Feb-28</td>
</tr>
<tr>
<td>8, 9, 10</td>
<td>Mar-03 to Mar-21</td>
<td>Circuit design project</td>
<td>Mar-21</td>
</tr>
<tr>
<td>11, 12</td>
<td>Mar-24 to Apr-04</td>
<td>Feedback and review</td>
<td>—</td>
</tr>
</tbody>
</table>

5.4 Other important dates

Monday, 6 January 2014: first class
Monday, 17 February 2014: Winter break begins (no classes this week)
Friday, 21 February 2014: Winter break ends
Friday, 7 March 2014: drop date
Friday, 4 April 2014: last class
Monday, 7 April 2014: examinations begin
Friday, 18 April 2014: holiday
Monday, 21 April 2014: examinations end

The last date to drop one-semester courses, without academic penalty, is Friday, 7 March 2014. Two-semester courses must be dropped by the last day of the add period in the second semester. Please consult the Graduate Calendar to verify the schedule of dates for this term:
http://www.uoguelph.ca/registrar/calendars/graduate/current/sched/sched-dates-w11.shtml

5.5 Obtaining help

You can obtain help during the instructor’s office hours and after lectures. Please come and talk to me if you have fallen behind in your work. I am willing to put in as much effort to help you as you are willing to put in to help yourself. I am happy to work with you on difficult concepts and hear your suggestions for ways to make the course better.

I hope you enjoy the course and I am looking forward to your feedback to make the material more interesting or more connected to your research activity or your final project. Do not hesitate to actively participate during lectures with questions and remarks. If something is not clear, please let me know. If you are excited about the subject and want to develop a project, contact me. Analog design is a lot of fun.

6 LABORATORY SAFETY

Safety is critically important to the School of Engineering and is a shared responsibility among faculty, staff, and students. As a student you are responsible for taking all reasonable safety precautions and following the approved safety procedures specific to the laboratory you are working in. In addition, you are responsible for reporting all safety issues to the laboratory supervisor or the faculty responsible.

Please use good judgement and safe working habits and remember that food and drink are not allowed in laboratories. In case of doubts about safety procedures please consult with the laboratory supervisor or the instructor before proceeding. Any violation of safety policies may result in loss of laboratory access.

You are required to comply with the University of Guelph Acceptable Use Policy for Information Technology, which is available on: https://www.uoguelph.ca/cio/content/aup-acceptable-use-policy. If you have any question about this policy, please ask the laboratory technician or the instructor.

7 ACADEMIC MISCONDUCT

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community (faculty, staff, and students) to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University’s policy on academic misconduct regardless of their location of study; faculty, staff, and students have the
responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member.

The academic misconduct policy is detailed in the Graduate Calendar:
http://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/sec_d0e1702.shtml

A tutorial on Academic Misconduct produced by the Learning Commons can be found at:
http://www.academicintegrity.uoguelph.ca/

The School of Engineering has adopted a Code of Ethics that can be found at:
http://www.uoguelph.ca/engineering/undergrad-counselling-ethics

You are encouraged to familiarize yourself with your responsibilities, review the tutorial on Academic Integrity, and discuss any question you may have with the instructor or a faculty member.

When writing laboratory and project reports, please remember that copying text, data, or figures is plagiarism, even if you received the material from a friend or you found it on the Internet. Letting others use your work is also not allowed, please keep your reports, designs, and simulation results in a secure location.

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8 Accessibility

The University of Guelph is committed to creating a barrier-free environment. Providing services for students is a shared responsibility among students, faculty and administrators. This relationship is based on respect of individual rights, the dignity of the individual and the University community’s shared commitment to an open and supportive learning environment. Students requiring service or accommodation, whether due to an identified, ongoing disability or a short-term disability should contact the Centre for Students with Disabilities as soon as possible.

For more information, please contact the Centre for Students with Disabilities at ext. 56208 or email csd@uoguelph.ca or see the website: http://www.uoguelph.ca/csd

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9 Recording of Materials and Copyright

Presentations which are made in relation to course work, including lectures, cannot be recorded or copied without prior permission of the presenter, whether the instructor, a classmate or guest lecturer. Material recorded with permission is restricted to use for this course unless further permission is granted.

The instructor reserves the right to all materials made available for this course and all interpretations presented in class, which may not be reproduced, transmitted to others, stored, or archived in electronic
backup media without the written consent of the instructor. The resources that are made available during course activities or through the course web page or the University IT infrastructure may be protected by copyright, technology usage agreements, or non-disclosure agreements and are only for the use of students enrolled in this course for the purposes associated with this course and may not be retained or further disseminated.

10 RESOURCES

The Academic Calendars are the source of information about the University of Guelph’s procedures, policies and regulations which apply to undergraduate, graduate and diploma programs.

This course outline includes sections and standard statements adapted with permission from the course outline template of the School of Engineering and from the course outline checklist of the University of Guelph. In case of any discrepancy, please refer to the current Academic Calendars.