Course Handbook

Course unit title: Microelectronic Devices and Circuits, EEE250
Type of course unit (compulsory, optional): Compulsory
Year of study (if applicable): 2nd year
Semester/trimester when the course unit is delivered: Semester 6
Number of ECTS credits allocated: 6 ECTS Credits
Name of lecturer(s): Prof Alex James
Teaching Assistants (s):
Mode of delivery (face-to-face, distance learning): face to face and online
Prerequisites and co-requisites: Introduction to Electrical Engineering, Digital Electronic Systems Design
Recommended optional programme components: Physics

Summary

This module provides theoretical and conceptual foundations required to understand semiconductor devices. The module largely focuses on various aspects of device physics, modelling and computer simulations. Further, this module also provides the basic frameworks for building non-linear circuits with PN junction and MOS devices.

Aims

The main aim of the module is threefold:
1. Provide foundational knowledge required to understand deeper concepts in semiconductor devices
2. Develop circuit design skills in line with understanding of physical mechanisms of semiconductor devices
3. Apply the knowledge of semiconductor devices to build circuits and simulate them reflective of realistic conditions.

Learning outcomes of the course unit

1. Students are expected to relate simulations with the theory
2. Apply the conceptual understanding of device working in simulation and modelling of semiconductor devices
3. Understand the working of semiconductor circuits and their characterization using simulations and experimental analysis
4. Be able to extensively use circuit design and modelling tools such as SPICE
5. Develop effective written technical communication through a well written and presented project report

Understanding ECTS and Workload

1. 1 ECTS credits is equal to an estimate of 25 to 30 hrs of work for an average student
2. 6 or 5 ECTS credits is about 150 to 180 hrs of work hours to complete the course study.
3. The ECTS credit is only an estimate and the number of actual hours spend by the student depends on the student (it can be more or less than the specified average hours), and the nature of learning activity within a course.
4. Its very unlikely that two 6 or 5 credit courses have same workload, and hence should not be compared (this a very basic idea of ECTS system).

**Grade distribution**
There are relative and absolute graded components in this course. Normalization to the grades is expected to lead to a higher distribution of marks that what it would be in actual, for example in this course, it is expected to turn out to be:

A:5%, A-:10%, B+:20%, B:30%, B-:20%, C+:10%, C:5%

Note: This is only tentative and can significantly vary depend on the actual performance in the class.

**Class policy**

1. Attendance is compulsory in all lectures and labs, and will be strictly monitored. **Overall, if the attendance falls below 90% in lectures and 100% in labs, you will be failed in the course.**
2. Taking part in all tutorials are recommended as they are linked to exam questions and you are requested to seek the advice of Professor from time to time.
3. Deadlines are not negotiable and late submissions irrespective of reasons carry a penalty of 100% reduction in marks. 10% bonus marks will be provided to the completed works submitted in full standing within the first 24 hours of the submission announcement.
4. Grades are not negotiable. Any attempt to manipulate your personal and professional situations to justify the need for a change in grades will be treated as academic misconduct.
5. Plagiarism is any form in/during any component of the course will result in failure grade.
6. Absences in any form will be treated equally. There won’t be any form of consideration on extension of deadline for excused or non-excused absences.

**Student responsibilities**
Students are expected to be responsible for their actions:

1. Keep deadline
2. Be on-time on all lectures, tutorials and labs
3. Attend all lectures, tutorials and labs
4. Consult professor and teaching assistant frequently as required
5. Actively engage in the class
6. Avoid sleeping and misbehaviour
7. Understand grading, workload requirements and time management
8. Follow the class policy

**Professor Consultation**
Students are encouraged to fix up an appointment with the professor in case of following
situations:
1. You have problems understanding a lecture material
2. Find the problems to be too difficult and need additional help
3. Not able to keep up with the deadlines
4. Feel emotionally drained and academic work seems heavy
5. Have difficulty with project design and development
6. Need advice on career opportunities in integrated circuits
7. Need advice on graduate study in the area
8. You have any concern to raise that is effecting your study
9. You feel demotivated and lost
10. You feel exceptionally good and want to share your thoughts
11. You want to share some great ideas
12. You want to work on a research idea

Note: There are no specific office hours. You are free to come and meet me anytime (including weekends) for consultation upon our mutual convenience. You can book the appointments via email.

Communication

Online discussion group: Students are encouraged to join the Q&A discussion group in moodle. Where you are encouraged to post the questions you have, all students are invited to participate inking writing reply to the questions.

There will be 3 feedback survey done during the course. You could raise your concerns in a constructive manner to improve your study experience. Any specific concerns or positive thoughts that you as an individual want to discuss can be directly raised to the professor in confidence through email or meeting in person. Your feedback will be taken seriously by the professor and Prof James will be available throughout to make your study experience as smooth as possible.

Understanding ECTS grades


The grades have an expected distribution as outlined in the european commission that monitors the bologna process, that Nazarbayev University is also following. Here is the expected grade plan followed for this course. We would be following relative grading for all components in the course except the final exam and that is specified in this document. Please note that these are only estimates and will depend on student performance and successful course completion.

Course contents:

• Introduction to the theory of electrons and holes in semiconductors
• Motion and recombination of electrons and holes
• Device fabrication technologies and issues
- PN and metal in semiconductor junctions
- Metal oxide semiconductor capacitors
- Metal oxide semiconductor transistors
- MOSFETs modelling and practical design issues in integrated circuits
- Bipolar transistors

**Schedule Lectures**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time and Room</th>
<th>Type</th>
<th>Mandatory attendance</th>
<th>Tasks assigned</th>
<th>In-class activities</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 Aug 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>23 Aug 2016</td>
<td>4:30pm-5:30pm, 6507</td>
<td>Tutorial Lecture</td>
<td>Yes</td>
<td>Lab work 1</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>25 Aug 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 1</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>1 Sep 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 1</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>8 Sep 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 1</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>15 Sep 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 2</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>29 Sep 2016</td>
<td>9am-11am, 6105</td>
<td>Exam</td>
<td>Yes</td>
<td>Lab work 2</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>6 Oct 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 2</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>20 Oct 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 2</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>3 Nov 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 3</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
<tr>
<td>10 Nov 2016</td>
<td>9am-11am, 6105</td>
<td>Lecture</td>
<td>Yes</td>
<td>Lab work 3</td>
<td></td>
<td>Discussion, peer-review</td>
</tr>
</tbody>
</table>
Recommended or required reading:

BSIM manuals: http://www-device.eecs.berkeley.edu/bsim/

Teaching and learning methods

The module is largely focused on:
1. Project based learning
2. Flipped learning (or blended learning)

In this approach, the students are expected to come prepared for the lecture well ahead of the actual lecture day. The students need to go through to the posted lecture notes or materials as assigned to them. The lecture hours would have activities more than typical delivery of lectures. The students will be required to give a wide range of classroom presentations on a regular basis.

To make the learning active, this course does not include any formal submission of assignments other than that of the labs or project reports.

Major Assessments

<table>
<thead>
<tr>
<th>Item</th>
<th>Format</th>
<th>Attendance</th>
<th>Deadlines</th>
<th>Assessment Type</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion 1</td>
<td>Online</td>
<td>Monitored</td>
<td>31 Aug 2016</td>
<td>Formative, Peer-review</td>
<td>5%</td>
</tr>
<tr>
<td>Discussion 2</td>
<td>Online</td>
<td>Monitored</td>
<td>28 Sep 2016</td>
<td>Formative, Peer-review</td>
<td>5%</td>
</tr>
<tr>
<td>Lab exam 1</td>
<td>Viva</td>
<td>Monitored</td>
<td>1 Oct 2016</td>
<td>Summative</td>
<td>5%</td>
</tr>
<tr>
<td>Lab exam 2</td>
<td>Viva</td>
<td>Monitored</td>
<td>12 Nov 2016</td>
<td>Summative</td>
<td>5%</td>
</tr>
<tr>
<td>Mid-term</td>
<td>Online</td>
<td>Monitored</td>
<td>26 Sep 2016</td>
<td>Summative</td>
<td>20%</td>
</tr>
<tr>
<td>Project</td>
<td>Online &amp;</td>
<td>Monitored</td>
<td>21, 23, Nov</td>
<td>Summative</td>
<td>20%</td>
</tr>
<tr>
<td>Presentations</td>
<td>2016</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final exam</td>
<td>Classroom</td>
<td>Monitored</td>
<td>Dec Week 1</td>
<td>Summative</td>
<td>40%</td>
</tr>
</tbody>
</table>

**Open Labs**

Every week you have lab. All labs will have mandatory attendance.

**Examinations**

All the examinations – i.e. the mid-term and final exams will have 4 components: (1) short answer type questions largely based on the textbook theory (40%), (2) questions focused on conceptual understanding that often requires exploratory learning (40%), (3) questions focused on practical skills and concepts as identified and developing during the labs and projects (15%), and (4) finally advanced questions that require deep knowledge in the subject, that goes well beyond the minimum standards of the course (5%).

<table>
<thead>
<tr>
<th>Question type</th>
<th>Percentage marks</th>
<th>Credit type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short answer (1)</td>
<td>40%</td>
<td>Mandatory, regular</td>
</tr>
<tr>
<td>Conceptual (2)</td>
<td>40%</td>
<td>Mandatory, regular</td>
</tr>
<tr>
<td>Practical (3)</td>
<td>20%</td>
<td>Mandatory, regular</td>
</tr>
<tr>
<td>Advanced (4)</td>
<td>60%</td>
<td>Advanced, bonus</td>
</tr>
</tbody>
</table>

**Language of instruction:** English  
**Work placement:** Project week - work on a 1 credit project

**Group Design Project**

This is an open ended design project. Each project needs to have at least 3 team members. And identify 1 team leader. Every team member is expected to contribute in the technical level. The students are expected to comply with the following timeline:

<table>
<thead>
<tr>
<th>Item</th>
<th>Deadline</th>
<th>Percentage Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract and title</td>
<td>1 Sep 2016</td>
<td>5%</td>
</tr>
<tr>
<td>Proposal document</td>
<td>15 Sep 2016</td>
<td>15%</td>
</tr>
<tr>
<td>Submission preliminary</td>
<td>3 Nov 2016</td>
<td>20%</td>
</tr>
<tr>
<td>results</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working prototype and Video</td>
<td>22,24 Nov 2016</td>
<td>30%</td>
</tr>
<tr>
<td>presentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report</td>
<td>25 Nov 2016</td>
<td>30%</td>
</tr>
</tbody>
</table>

Note: High standards are expected in the overall functioning of the project.

Things to submit:  
1. Project report (IEEE Transactions format) - limit to 15 pages; maximum 100 references;  
   Only PDF files with LaTeX source files will be accepted.  
2. Spice Simulation files and schematics  
3. Working prototype
Laboratory Exercises

Lab 1:
Characterize the following devices in SPICE.
1. Resistor
2. Capacitor
3. Non-linear resistors
4. Memristor
5. Photo diode
6. PN diode
7. MOSFET
8. BJT
For all the devices give the details of the models used, include what effects are considered. Include a IV, CV and transient characteristics where ever applicable.

Lab 2:
Characterize the following devices using laboratory equipments and compare your results with that obtained in SPICE.
1. Resistor
2. Capacitor
3. Non-linear resistors
4. Memristor
5. Photo diode
6. PN diode
7. MOSFET
8. BJT
For all the devices give the details of the models used, include what effects are considered. Include a IV, CV and transient characteristics where ever applicable. Extract the device parameters from the measured data.

Lab 3:
You are required to develop practical skills for soldering and PCB design in this lab. This is a project based lab, where you need to identify a circuit that can used for device characterization. For example, a Wheatstone bridge circuit can be used to measure resistances changes etc (see http://www.ti.com/lit/ml/slyp163/slyp163.pdf).