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Course Outline

Carleton University

Department of Electronics Engineering

ELEC 3908 – Physical Electronics – Winter 2021

Course Outline

Introduction:

This course examines the structure, fabrication, physical operation and modeling of semiconductor diodes, bipolar transistors and MOSFETs.

Instructor: Tom Smy

Office: 4154 Mackenzie

Email: tom.smy@carleton.ca

Web page: https://www.doe.carleton.ca/~tjs/

Course Site: Course webpage on BrightSpace

Course Structure

I intend to run the course somewhat differently than previously. Due to the on-line mode of instruction over the last two years I have two years of recorded lectures. After reviewing these lectures I think that they are a better learning tool than a live lecture. And this presents an opportunity to create some more active learning situations. I will be using the lecture time in this course to create small group learning situations that I will lead. Details on this will be found in the Seminar module. The basic intent is that you will watch

the lectures online and then attend seminars during the week. The seminar will be a combination of material highlights and Q and A.

Teaching Assistants:

1. N/A

Lectures: On on-line video.

Seminars: 1/2 hour small group seminars for discussion and Q/A. Done during scheduled lecture time.

Course Pack: A course pack containing PDF of summary course notes is available on the BrightSpace course homepage. Weekly lecture notes and sample problems will be made available.

Tutorial Sessions: Tutorial sessions will be held by the teaching assistants for a duration of three hours per week prior to quizzes. Please refer to the course schedule available on BrightSpace to learn more about the timing of tutorial sessions.

Lab Sessions: Typically groups of two students will be assigned to work together to collect data. Analysis of the data and associated calculations are to be done individually.

All lab reports, which must include all the required material compiled into a single PDF, will be due on BrightSpace by midnight on the seventh day following the lab, unless otherwise indicated. You must include the name of your lab partner(s) on the cover page of your report. Attending the lab period and the proper collection of required data accounts for approximately half of the lab grade and the analysis of YOUR data for the other half. There is a 10%/day penalty for late reports - submission of all lab reports is MANDATORY for successful completion of the course.

Quizzes and Final Exam: Three quizzes, designed to be 60-minutes long, will be held during the term in the PA sections. The final exam will be three-hours long.

If you miss a quiz with a valid reason, you can request to take a make-up quiz. As per University policy, the quiz portion is not transferred to the final exam.

Calculator Policy: Programmable calculators will not be allowed in the quizzes or final exam. A “programmable calculator” is defined as a calculator that can store program steps or text at any level of sophistication and the rule applies irrespective of whether or not there appears to be anything stored. If you have any doubts about the eligibility of your calculator, please see me well before the exam. You can’t use your cell phone.

Course Grade: The final grade will be determined using the following weighting.

- Quizzes (3@10% each) 20%
- Labs (3@5% each). 15%
- Final Exam 50%
- Seminars 5%
- Excellent Questions 5%. (Bonus)

Please view the following link:
https://www3.carleton.ca/calendars/ugrad/0910/regulations/acadregsuniv14.html

Quiz, Exam and Lab grade listings: All in-term assessment grades will be posted on the course BrightSpace website. Students will be notified through BrightSpace announcements about marks posting. Please check your marks online and report any discrepancies immediately. Errors must be reported to the appropriate marking TA during TA office hour. Please monitor the course website any changes to marking and assessments.

Final Exam Availability: In keeping with University policy: Students have the right to have questions regarding their grades addressed and to view all material, including material that has not been returned such as final examinations. In some cases, the original submitted work will remain in the possession of the University and the viewing of this work may be supervised. In cases where a student has concerns regarding the determination of their final grade, the student will be provided with a list of their grades on all components of the course and a description of how their final grade was calculated.

Graduate Attributes: An institution must demonstrate that graduates of its programs possess the attributes described below. In addition, the institution must implement and employ processes to demonstrate that program outcomes are being assessed in the context of these attributes, and that the results of such assessments will be applied to the further development of programs. The graduate attributes are:

1. *A knowledge base for engineering:* Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
2. *Problem analysis:* An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.
3. *Investigation:* An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.
4. *Design:* An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

5. *Use of engineering tools:* An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6. *Individual and team work:* An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.
7. *Communication skills:* An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8. *Professionalism:* An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
9. *Impact of engineering on society and the environment:* An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.
10. *Ethics and equity:* An ability to apply professional ethics, accountability, and equity.
11. *Economics and project management:* An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.
12. *Life-long learning:* An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

In ELEC 3908, student work is assessed to score graduate attribute 1 (knowledge base; KB) for engineering. The graduate attribute scores may be derived through one or more quiz and exam grades however the graduate attribute scores are not used in determination of the final grade for the course.

Academic Accommodation: You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows: Pregnancy obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details visit the Equity Services website: http://www.carleton.ca/equity/ Religious obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details visit the Equity Services website: http://www.carleton.ca/equity/

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder

(ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable) at http://www.carleton.ca/pmc/new-and-current-students/dates-and-deadlines/ You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at http://www.carleton.ca/equity/

Use of Course Materials: Classroom teaching and learning activities, including lectures, discussions, presentations, etc., by both instructors and students, are copyright protected and remain the intellectual property of their respective author(s). All course materials, including PowerPoint presentations, outlines, and other materials, are also protected by copyright and remain the intellectual property of their respective author(s). Students registered in the course may take notes and make copies of course materials for their own educational use only. Students are not permitted to reproduce or distribute lecture notes and course materials publicly for commercial or non-commercial purposes without express written consent from the copyright holder(s).

Equation Sheet

Exam sheet for final exam.

ELEC 3908-W2021-Comprehensive Help Sheet - 4 pages
PDF document

Seminars

Some change to the seminar structure.

At the beginning of each Mon/Wed slot at 4:00 I'm going to give a brief review of the material for that week -- it will be the same review on both days. So everybody is welcome to come at 4:00 if they wish. The rest of the time will be for questions and you can go and come as you see fit. You can still use the groups if you wish to simply ask questions.

There is also a discussion section at the bottom of the Seminar module where I would like you to enter your questions rather then email them to me. We can thread them by weeks and you can open a new thread if that week has not been initiated.

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Due to the on-line mode of instruction over the last two years I have two years of recorded lectures. After reviewing these lectures I think that they are a better learning tool than a live lecture. And this presents an opportunity to create some more active learning situations in small group seminars.

These seminars will run in the regular lecture slots. They will be nominally 1/2 an hour long and you will be assigned to a particular slot on either Monday or Wednesday. This is to create a small group of students. However, you are welcome to come to other slots.

The intent is to create small group learning situations that I will lead. The basic intent is that you will watch the lectures online prior to the seminar and then attend the seminar during the week. The seminar will be combination of material highlights and Q and A. The primary goal of the seminar is to get you to **engage** with the material and get into an active discussion. You should make notes when you watch the lecture material noting:

- When I say something confusing
- When you get lost.
- When I make a mistake.
- If something seems interesting and you want more detail.

Using these notes create questions for the seminar. Ideally email me your questions prior to the seminar, but if not just ask at the seminar itself.

I'm hopeful that these seminars will be an efficient way for you to learn/study the material. I'm aware that you will already be spending time watching the videos which is why I'm only assigning 1/2 hour seminars, but if the seminars are lively I think you will learn a lot more during that 1/2 hour than you would studying by yourself -- saving time overall.

The success of this is in large part down to **you** as it will only work if you are motivated and engaged.

To motivate these discussion I'm setting a 5% mark assignment for seminar engagement and 5% bonus for coming up with great questions.

Seminar Questions
Discussion Topic

Add your questions here.

Week 1
PowerPoint Presentation

Week 2
PowerPoint Presentation

Week 3
PowerPoint Presentation

Lectures

Lectures are on-line video and you have two years of recordings: 2020 and 2021. The 2021 recordings are the most relevant. You should watch the videos prior to attending your seminar and bring questions. PDF of the lecture material is below.

It might be useful to watch the lectures in small informal groups. You can discuss, take notes and collect questions.

Recordings from 2021 are embedded in the weekly modules.

Here is a link to Lectures from 2020.

Lectures
Web Page

This is the recording of the introductory Week 0 Lecture... Recording

Week 1

Sept. 12 and 14 - Diodes and Semiconductors

Week 1 - Lecture 1
PDF document

Week 1-2 - lecture 2-3-updated
PDF document

ELEC 3908 Lecture 2 [Smy 2021]
PowerPoint Presentation

Week 2

Sept. 19 and 21 - IC fabrication and diodes

Week 2 - lecture 3-4
PDF document

Week 2 - lecture 4
PDF document

Week 3

Sept. 26 and 28 - Doping Profiles and Transport

Week 3-lecture 1-updated-with examples
PDF document

Week 3-lecture 1-updated
PDF document

Week 3-lecture 2-updated
PDF document

Week 4

Oct. 3 and 5 - Diode Operation and Parasitics

Week 4-lecture 1-updated
PDF document

Week 4-lecture 2
PDF document

Week 5

Oct. 12 - Diode Electrostatics and Breakdown (no seminars on 10th as it's a holiday come on the 12th)

Week 5-lecture 1-updated
PDF document

Week 5-lecture 1
PDF document

Week 5-lecture 2
PDF document

Week 6

Oct. 17 and 19 - Diode Small Signal Model/Switching and BJT Intro.

Week 7-Lecture 1-updated
PDF document

Week 7-Lecture 2-updated
PDF document

Week 7

Reading Week

Drag and drop files here to create and update topics

Week 8

Oct 31 and Nov 2 - BJT Basic Theory

Week 8 Lecture 1
PDF document

Week 8 lectures 1 and 2 combined
PDF document

Week 9

Nov. 7 and 9 - BJT Beyond the standard model

Week 9 - Lecture 1-updated
PDF document

Week 9 - Lecture 2-updated
PDF document

Week 10

Nov. 14 and 16 - Mosfet Structure and Operation

Week 10 - Lecture 1
PDF document

Week 10 - Lecture 2-updated
PDF document

Week 10 - Lecture 2
PDF document

Week 11

Nov. 21 and 23 - Mosfet V_{th} and the Square Law Model

Week 11 - Lecture 1-updated
PDF document

Week 11 - Lecture 2-updated
PDF document

ELEC 3908 Lecture 22 [Smy 2021]
PDF document

Week 12

Nov. 28 and 30 - Mosfet Short Channel Effects

Week 12 - lecture 1
PDF document

Week 12 - lecture 2
PDF document

Week 13

Dec. 5 and 7 - Mosfet Small Signal Model and Review

Week 13 - Lecture 1-updated
PDF document

ELEC 3908 Lecture 26_27 [Smy 2021]
PDF document

Week 13 - Lecture 2
PDF document

Elec3908-Final Review-Winter 2021
PDF document

Tutorials

And Here you will find all to do with tutorials.

Tutorials will focus on problem solving. There are currently tutorials scheduled on:

1. Tutorial 1 Sept 29/30
2. Tutorial 2 Oct 20/28
3. Tutorial 3 Nov 17/18

Problem Sets

BJTTutorial
PowerPoint Presentation

MosfetTutorial
PDF document

Course Pack

Course Pack by Steve McGarry -- This is excellent and FREE!

ELEC 3908 Course Pack [Prof. Steven McGarry]
PDF document

Quizzes

And Here you will find everything to do with quizzes.

Quizzes are done in person in the PA.

Quiz Dates:

1. Quiz 1 Oct 6/7
2. Quiz 2 Nov 3/4
3. Quiz 3 Nov 24/25

Labs

And Here you will find all to do with labs.

Labs must be done in person in your lab section.

Lab write ups are individual. Please see the Lab Guidelines below. **On each write up indicate which station you used.**

TAs:

- N/A

Schedule:

Lab-0: Sept 22/23 (No write-up, but attendance will be taken)

Lab-1: Oct 13/14

Lab-2: Nov 10/11

Lab-3: Dec 1/2

This is the file for exporting from ICCap csvio.py as the link does not work. If the file that is present on the c: drive of your station seems to misbehave replace it with this one.

The formatting of the labs is an abomination. I have been unable to obtain the original word documents and converted them from the pdf back to Word -- which has produced a mess. Equations were a real mess and some of the math I've replaced in part with latex, but some of the inline math is still a mess. But I hope it is clear enough. I also hate Word. **Did I mention that I hate Word.**

Ok I couldn't take the Word Mess and have made a first attempt at Latex'ing the Labs 1-3. I may have introduced some bugs so I've provided both the Word and the Latex.

Did I mention that I hate Word.

Lab submission template
Word Document

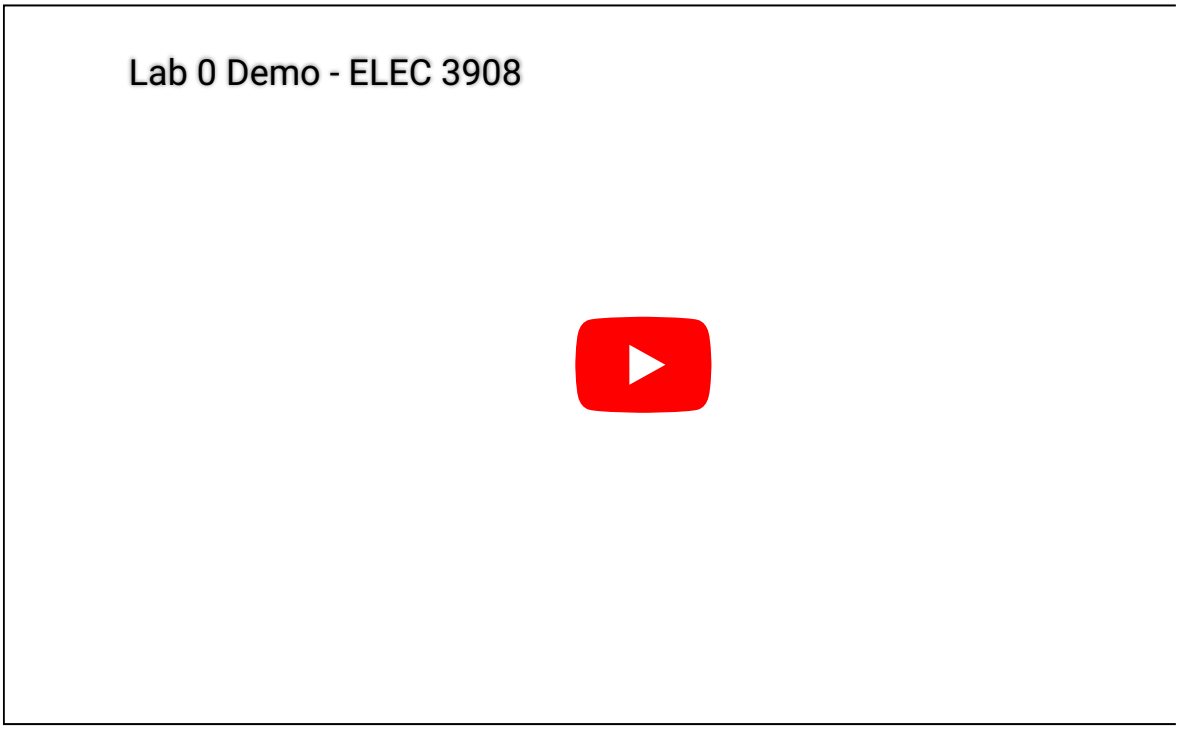
Lab 0

Lab 0 - An introduction to HP4145 and IC-CAP

Hi all,

Please go through the two instruction manuals carefully and complete the procedures outlined in the IC-CAP instructions. After completing these inform a TA

A video demo on using ICCAP for measurement and device modelling was prepared by Bruno Gamero, and is now available in the lab 0 demo folder. In addition, a detailed video demo on how to use the HP4145 semiconductor parameter analyzer on campus was prepared by Kevan MacKay, and is available at:



I would highly encourage that you go through these two informative demos before completing lab 0.

You can work individually (if there are enough stations) or in groups of two. Find a station and inform the TA.

This is the file for exporting from ICCap csvio.py as the link does not work. If the file that is present on the c: drive of your station seems to misbehave replace it

with this one.

Best regards,

Tom

LAB 0 HP4145 Parameter Analyzer Tutorial
PDF document

Lab 0: IC-CAP instructions
PDF document

Lab0-ICCAP
Video

Lab 1

In this lab you will measure the DC behavior of a number of diodes.

1N4148
PDF document

1N4728-4764
PDF document

diode_model
CIR File

DiodeLatex
PDF document

ELEC 3908 Lab 1 Diode
PDF document

ELEC3908_Lab1_Diode1
MDL File

ELEC3908_Lab1_Diode2
MDL File

Python files
Zip Compressed File

Lab 2

In this lab you will measure the DC characteristics of a BJT.

2N3904_model
CIR File

2N3904
PDF document

BJTLabLatex
PDF document

ELEC 3908 Lab 2 BJT testing and simulation
PDF document

ELEC3908_Lab2_BJT
MDL File

Lab 3

In this lab you will measure the DC characteristics of a MOSFET.

cd4007ub
PDF document

MosfetLatex
PDF document

ELEC 3908 Lab 3 MOSFET
PDF document

MOSFET
CIR File

Python files
RAR File

4705 links

4705 Lectures
Web Page