THE UNIVERSITY OF BRITISH COLUMBIA

Irving K. Barber Faculty of Science
Okanagan Campus

Department of Computer Science, Mathematics, Physics and Statistics

PHYS 231 - Section 1
Introduction to Electronics (3 credits)
2021 – Winter Term 1
Except for homework (submitted through Canvas), all components of this course including labs, lectures, midterm test, and final exam will be completed in-person.

In-Person **Lecture**	Tue	13:00	14:00	EME 2111
In-Person **Lecture**	Thu	13:00	14:00	EME 2111
Laboratory L01 In-Person	Wed	11:00	14:00	SCI 241
Laboratory L02 In-Person	Tue	14:00	17:00	SCI 241

- You must register in one of the lab sections.

Instructor:
Name: Reza Khanbabaie, PhD
Office: ASC 286
Phone: TBA
E-mail: reza.khan@ubc.ca

Office Hours: Thu 2:00–3:00 pm, my office

TA for Lecture: Maya Patel — Message through Canvas (Main course shell)
TA for Lab L01: Maya Patel — Message through Canvas (Main course shell)
TA for Lab L02: Marshall Jacob — Message through Canvas (Main course shell)

Course Description:

PHYS 231 (3) Introduction to Electronics

Design and analysis of analog AC circuits, digital circuits, and analog-to-digital conversion methods. Basic physics laboratory skills including data collection, presentation of results, and analysis of uncertainties.

Credit will be granted for only one of PHYS 231 or PHYS 219. [2-3-0]

Prerequisite: MATH 101 and one of PHYS 102, PHYS 121, PHYS 122.

About this course:

We introduce Electronics through designing a very simplified cellular phone and show that we need to understand the physics of semiconductors. After reviewing the electrical circuit theorems, we will study the basic physics of semiconductors. The rest of this course will focus on diodes, transistors, amplifiers, and different models of them. We will learn microelectronics from a modern and intuitive perspective.

Overview

In this course you will study, build, and then analyze a variety of analog and digital circuits. In most cases you, will build your circuits and collect the required data in a single lab period. At the end of the term you will use what you have learned to build a more sophisticated circuit that makes use of both analog and digital components. This end-of-term project will span several classes (at least three).

In physics, the vast majority of experimental data are derived from electronic signals that must be acquired and processed. In this course, you will encounter all aspects of practical circuits { from design and construction to testing and debugging. Other skills that you will develop include: working with standard test equipment (multimeters, function generators, and oscilloscopes), data analysis, and keeping a thorough and neat log of your work that succinctly describes the technical details of each task that you complete. Each of these skills are required to be successful in any experimental physics laboratory.

The lecture portion of the course will be used develop a theoretical understanding of electronics. Methods used to analyze practical circuits will be emphasized. The lectures will also present the background information relevant to the circuits that you will study in the laboratory. Some topics covered in PHYS 102/121/122 may be reviewed, but they will not be repeated in great detail.

Attendance is mandatory for both the lecture and laboratory sessions.

In the Lecture & Lab

The TAs and I will do our best to present material and respond to questions in a clear and logical way. However, you must take responsibility for your own learning. Come to the lab prepared. *Read* and *study* the manual *before* coming to the lab, *ask* questions, *ask* for clarification, *contribute* to discussions, *offer* ideas, . . .

There will be assignments throughout the term. The assignments will allow you to apply what you've learned in the lectures and from the textbook. They will also prepare you for upcoming labs.

You will not be permitted to work on assignments during the lectures or labs.
Be considerate of fellow students: no cell phones, texting, reading email, web browsing, social networking, . . . during class.

The materials we cover for the Lecture Section are as follows:

Chapter 1: Introduction to Microelectronics

The objective of this chapter is to provide the "big picture" and make the students comfortable with analog and digital signals.

1.1 Electronics versus Microelectronics
1.2 Examples of Electronic Systems
- **1.2.1** Cellular Telephone
- **1.2.2** Digital Camera
- **1.2.3** Analog Versus Digital

1.3 Basic Concepts
- **1.3.1** Analog and Digital Signals
- **1.3.2** Analog Circuits
- **1.3.3** Digital Circuits
- **1.3.4** Basic Circuit Theorems

Chapter 2: Basic Semiconductor Physics

2.1 Semiconductor Materials and Their Properties
- **2.1.1** Charge Carriers in Solids
- **2.1.2** Modification of Carrier Densities
- **2.1.3** Transport of Carriers

2.2 *pn* Junction
- **2.2.1** *pn* Junction in Equilibrium
- **2.2.2** *pn* Junction Under Reverse Bias
- **2.2.3** *pn* Junction Under Forward Bias
- **2.2.4** I/V Characteristics

2.3 Reverse Breakdown
- **2.3.1** Zener Breakdown
- **2.3.2** Avalanche Breakdown

Chapter 3: Diode Models and Circuits

3.1 Ideal Diode
- **3.1.1** Initial Thoughts
- **3.1.2** Ideal Diode
- **3.1.3** Application Examples

3.2 *pn* Junction as a Diode
3.3 Additional Examples
3.4 Large-Signal and Small-Signal Operation

- 3.5 Applications of Diodes
  - **3.5.1** Half-Wave and Full-Wave Rectifiers
  - **3.5.2** Voltage Regulation
  - **3.5.3** Limiting Circuits
  - **3.5.4** Voltage Doublers
  - **3.5.5** Diodes as Level Shifters and Switches

Midterm Exam, 10%, Date and Time: TBA

Chapter 4: Physics of Bipolar Transistors

- 4.1 General Considerations
- 4.2 Structure of Bipolar Transistor
- 4.3 Operation of Bipolar Transistor in Active Mode
  - **4.3.1** Collector Current
  - **4.3.2** Base and Emitter Currents
- 4.4 Bipolar Transistor Models and Characteristics
  - **4.4.1** Large-Signal Model
  - **4.4.2** I/V Characteristics
  - **4.4.3** Concept of Transconductance
  - **4.4.4** Small-Signal Model
  - **4.4.5** Early Effect
- 4.5 Operation of Bipolar Transistor in Saturation Mode
- 4.6 The *PNP* Transistor
  - **4.6.1** Structure and Operation
  - **4.6.2** Large-Signal Model
  - **4.6.3** Small-Signal Model

Chapter 5: BIPOLAR AMPLIFIERS

- 5.1 General Considerations
  - **5.1.1** Input and Output Impedances
  - **5.1.2** Biasing
  - **5.1.3** DC and Small-Signal Analysis
- 5.2 Operating Point Analysis and Design
  - **5.2.1** Simple Biasing
  - **5.2.2** Resistive Divider Biasing
  - **5.2.3** Biasing with Emitter Degeneration
  - **5.2.4** Self-Biased Stage
  - **5.2.5** Biasing of *PNP* Transistors
- 5.3 Bipolar Amplifier Topologies
  - **5.3.1** Common-Emitter Topology

8.2.4 Voltage Adder
8.3 Nonlinear Functions
8.3.1 Precision Rectifier
8.3.2 Logarithmic Amplifier
8.3.3 Square-Root Amplifier
8.4 Op Amp Nonidealities
8.4.1 DC Offsets
8.4.2 Input Bias Current
8.4.3 Speed Limitations
8.4.4 Finite Input and Output Impedances
8.5 Design Examples

* We will try our best to cover most of the materials listed above, however in practice we will cover as much as possible.

Final Exam, 30%, Date and Time: TBA

The materials we cover for the Laboratory Section are as follows:

Lab 1 Introduction to Laboratory Electronics
- Introduction to SPICE and TINA-TI
- Transient Analysis
- DC Analysis

Lab 2 Electronic Test Equipment
- DC Measurements (DMM and DC Power Supply)
- AC Measurements (Oscilloscope and Function Generator)

Lab 3 Kirchhoff and Ohm's Laws
- Ohm's Law
- Kirchhoff's Voltage Law
- Kirchhoff's Current Law
- Kirchhoff's Voltage Law and Phase

Lab 3 Transients in RC Circuits
- Rough Measurement of Time Constant with the Oscilloscope
- Measurement of the RC Time Constant with the DMM

Lab 4 AC & Transient Response of an LRC Circuit

- Transient Response
- Frequency Response

Lab 5 Diodes & Rectifier Circuits

- Halfwave Rectifier
- Improved Halfwave Rectifier
- Fullwave Rectifier
- Improved Fullwave Rectifier

Lab 6 Digital Basics

- Experimenting with Logic Gates
- Flip-Flop or Latch
- Counters

Lab 7 Bipolar Junction Transistor Characterization

- Determining the Region of Operation
- Determining the Early Voltage Using the Parameter Analyzer
- The BJT as a Diode
- The Darlington Pair (Super High β)

Lab 8-9 Final Project (this may take more than 2 sessions and will be considered as the Lab Midterm Exam, 10%)

- **Hands-on Project part** (**optional, up to 5% bonus**): students will have the option to build (physical building) a project based on the knowledge they acquire from this course. The Hands-On Projects cab be from simple devices to innovative devices and new ideas. Any innovation or novel idea will be highly appreciated.
  (should be submitted before the Final exam of PHYS 231)

Course Format:
Lectures will be delivered in-person by the instructor. There will be an Assignment after each chapter posted on Canvas. Assignment must be submitted before the due time. A Teaching Assistant (TA) will help me for marking the Assignments.

Lab Notebook

Your lab notebook is a very important part of the course. Your notebook should contain a complete log of what you do in the lab. It should include enough details that a knowledgeable person could reproduce your experiments and data analysis methods based solely on what you wrote in your notebook (without having the lab manual!). It should be complete and coherent enough that if you were to come back to your notebook several months (or years!) later, you would be able to understand exactly what you did in the lab. You need to write things down in your lab book as you do them (i.e. not on scrap paper and not sometime "later"). The notes in your log book should not refer readers to the lab manual.
At the beginning of the lab period the lab notebook containing the data and analysis from the circuit of the previous week will be collected. You will use your other notebook (remember, you need two) for the current experiment. Graded lab notebooks will also be returned at the start of the lab period.

Learning Outcomes:
After completing this course, students will be able to:

- Understand the difference between Electronics and Microelectronics, and Analog and Digital
- Set up differential equations that can be solved for the time evolution of voltages and currents in a circuit (time-domain analysis)
- Use complex algebra and the concept of impedance to determine the frequency dependence of amplitudes and phases of signals (voltage and current) in an ac circuit (frequency-domain analysis).
- Design practical op-amp circuits that perform useful tasks.
- Understand how doped semiconductors can be used to make diodes (one-way valves for current) and transistors (electric switches).
- Use transistor switches to design binary logic gates. Appreciate the advantages of digital electronics. Combine logic gates to perform useful tasks such as binary addition and counting.
- Construct sophisticated and practical analog and digital circuits.
- Use test equipment (power supplies, function generators, multimeters, oscilloscopes) to collect high-quality data from your circuits.
- Analyze the data that you collect from your circuits to extract meaningful results that can be compared to theoretical predictions.
- Apply proper error analysis methods (propagation of errors) to attach uncertainties to your measured data, the results of your analysis, and your theoretical predictions.

Passing Criteria:

Students must submit Assignments, write the Midterm Exams for Lecture and Lab, write the Final Exams for Lecture and Lab. There is no way to transfer the Midterm weight to Final since the final exam will not be accumulative.
To pass this course, your Final Mark must be on a passing grade (based on the standardized grading system outlined in the UBC Okanagan Calendar). The final mark will be calculated as:

Final Mark = Assignment (15%) + Lecture Midterm Exam (10%) + Lecture Final Exam (30%) + Lab Final Project (15%) + Lab Report (30%) + Hands-on Project (up to 5% bonus).

Required Materials:
Textbook: Fundamentals of Microelectronics, 2nd Edition, by Behzad Razavi, John Wiley & Sons, Inc.

Other References: 1. Basic Electronics for Scientists and Engineers by Dennis L. Eggleston.

2. Circuit Analysis and Design, by Ulaby, Maharbiz and Furse; **This book is available for free by the authors** (http://fet.eecs.umich.edu/)

You can attend the Lectures live or listen to the recorded lectures. Attending live or listening to the lectures are strongly recommended. Based on my experiences, I strongly suggest attending the lectures live.

Course Evaluation:

Item	Percentage	Date	Mand/Optional
Assignments	15%	One after each chapter	Mandatory
Lecture Midterm Exam	10%	After chapter 3	Mandatory
Lab Final Project	15%	Final project The last two sessions	Mandatory
Lab Reports	30%	TBA	Mandatory
Hands-On Project (HOP)	Up to 5% bonus	Before Final Exam	Optional*
Lecture Final Exam	30%	During Exam period	Mandatory
Total	100%		

Final Mark will be based on the evaluations listed above and the final grade will be assigned according to the standardized grading system outlined in the UBC Okanagan Calendar.
* If you scored more than 100% (with HOP), I will owe you a good recommendation letter!

Missed Assignments and Exams (if applicable) From UBC Okanagan Academic Calendar/Policies and Regulations/Academic Concession

"Students who, because of unforeseen events, are absent during the term and are unable to complete tests or other graded work, should normally discuss with their instructors how they can make up for missed work, according to **written guidelines given to them at the start of the course**. Instructors are not required to make allowance for any missed test or incomplete work that is not satisfactorily accounted for. If ill health is an issue, students are encouraged to seek attention from a health professional. Campus Health and Counselling will normally provide documentation only to students who have been seen previously at these offices for treatment or counselling specific to conditions associated with their academic difficulties. Students who feel that requests for consideration have not been dealt with fairly by their instructors may take their concerns first to the Head of the discipline, and if not resolved, to the Office of the Dean. Further information can be found at:
http://www.calendar.ubc.ca/okanagan/index.cfm?tree=3,48,0,0.

You must submit the Assignments before the due date. If a student is unable to submit an Assignment on time for a good and verifiable reason, he/she must notify the TA or instructor before the due time. There will be a possibility of extending the due time for that Assignment. If you notify the TA or Instructor after the solution of the Assignment is published, then there is no way to submit that Assignment. *Holidays are not acceptable reasons for missing Assignments.* If a student missed the Midterm Exam for a good and verifiable reason, he/she should talk to the Instructor as soon as possible. There is no way to transfer the weight of Midterm to Final.

Late Policy If any Assignments, and Exams are not taken on time or was not coordinated with the instructor, the mark will be considered Zero for that item.

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Grievances and Complaints Procedures

A student who has a complaint related to this course should follow the procedures summarized below:

- The student should attempt to resolve the matter with the instructor first. Students may talk first to someone other than the instructor if they do not feel, for whatever reason, that they can directly approach the instructor.
- If the complaint is not resolved to the student's satisfaction, the student should go to the departmental chair John Braun at SCI 388, 807-8032 or e-mail him at john.braun@ubc.ca.

Academic Integrity

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic

integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. **For example, incidences of plagiarism or cheating usually result in a failing grade or mark of zero on the assignment or in the course.** Careful records are kept to monitor and prevent recidivism.

A more detailed description of academic integrity, including the policies and procedures, may be found:

http://okanagan.students.ubc.ca/calendar/index.cfm?tree=3,54,111,0

If you have any questions about how academic integrity applies to this course, please consult with your professor.

Grading Practices

Faculties, departments, and schools reserve the right to scale grades in order to maintain equity among sections and conformity to University, faculty, department, or school norms. Students should therefore note that an unofficial grade given by an instructor might be changed by the faculty, department, or school. Grades are not official until they appear on a student's academic record. http://www.calendar.ubc.ca/okanagan/index.cfm?tree=3,41,90,1014 If you have any questions about how academic integrity applies to this course, please consult with your professor.

Disability Assistance

The Disability Resource Centre ensures educational equity for students with disabilities, injuries or illness. If you are disabled, have an injury or illness and require academic accommodations to meet the course objectives, visit our website for more information: http://students.ok.ubc.ca/drc/welcome.html or contact the DRC at: drc.questions@ubc.ca

Equity, Human Rights, Discrimination and Harassment

UBC Okanagan is a place where every student, staff and faculty member should be able to study and work in an environment that is free from human rights based discrimination and harassment. If you require assistance related to an issue of equity, discrimination or harassment, please contact the Equity Office, your administrative head of unit, and/or your unit's equity representative.

UBC Okanagan Equity Advisor: ph. 250-807-9291;

E-mail: equity.ubco@ubc.ca **Web:** https://equity.ok.ubc.ca/

Health & Wellness

At UBC Okanagan health services to students are provided by Health and Wellness. Nurses, physicians and counsellors provide health care and counselling related to physical health, emotional/mental health and sexual/reproductive health concerns. As well, health promotion, education and research activities are provided to the campus community. If you require assistance with your health, please contact Health and Wellness for more information or to book an appointment.

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Email: *healthwellness.okanagan@ubc.ca* Web: www.students.ok.ubc.ca/health-wellness

Sexual Violence Prevention and Response Office (SVPRO)

A safe and confidential place for UBC students, staff and faculty who have experienced sexual violence regardless of when or where it took place. Just want to talk? We are here to listen and help you explore your options. We can help you find a safe place to stay, explain your reporting options (UBC or police), accompany you to the hospital, or support you with academic accommodations. You have the right to choose what happens next. We support your decision, whatever you decide. Visit svpro.ok.ubc.ca or call us at 250.807.9640

Independent Investigations Office (IIO)

If you or someone you know has experienced sexual assault or some other form of sexual misconduct by a UBC community member and you want the Independent Investigations Office (IIO) at UBC to investigate, please contact the ***IIO***. *Investigations are conducted in a trauma informed, confidential* and respectful manner in accordance with the principles of procedural fairness. You can report your *experience directly to the **IIO** via email: director.of.investigations@ubc.ca or by calling 604.827.2060* or online by visiting investigationsoffice.ubc.ca

The Hub

The Student Learning Hub (LIB 237) is your go-to resource for free math, science, writing, and language learning support. The Hub welcomes undergraduate students from all disciplines and year levels to access a range of supports that include **tutoring in math, sciences, languages, and writing, as well as help with study skills and learning strategies**. For more information, please visit the Hub's website (https://students.ok.ubc.ca/student-learning-hub/) or call 250-807-9185.

SAFEWALK

Don't want to walk alone at night? Not too sure how to get somewhere on campus?

Call Safewalk at 250-807-8076.

For more information: https://security.ok.ubc.ca/safewalk/ or download the UBC SAFE – Okanagan app.