TO: The Faculty of the College of Engineering

FROM: Elmore Family School of Electrical and Computer Engineering

RE: New Graduate Course, ECE 50642 Essentials of Transistors

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 50642 Essentials of Transistors
Sem. 2, Lecture 3, Cr. 1, 5 weeks.
Prerequisite: ECE 30500 or ECE 606 or ECE "Semiconductor Fundamentals" (Permanent number will be ECE 60641
Prerequisites by Topic: Basic knowledge of undergraduate semiconductor device course (e.g., energy bands, doping, carrier densities, drift-diffusion equations, Fermi and quasi-Fermi levels

Description: This course is designed for anyone seeking a sound, physical, intuitive understanding of how modern transistors operate. Important technology considerations and applications of transistors are also discussed. The focus is on MOSFETs for digital logic, but other types of transistors are briefly considered. The course is broadly accessible to students with only a very basic knowledge of semiconductor physics and electronic circuits and should be useful for advanced undergraduates, beginning graduate students, as well as practicing engineers and scientists. Topics include device metrics for digital and analog circuits, traditional MOSFET theory, the virtual source model, 1D and 2D electrostatics, Landauer/transmission approach to nanotransistors, the limits of MOSFETs, as well as a quick look at HEMTs, bipolar transistors, and compact circuit models.

Reason: The transistor has been called the greatest invention of the 20th century – it enabled the electronics systems that have shaped the world we live in. This material is similar to about 5 weeks of ECE-612. Some of the basic MOS theory overlaps with ECE-606, but it will be taught at a higher level. The course is designed for students who don't take ECE-612. It is possible that some students who have taken 606 will also want to take this course, but ECE-606 is not a prerequisite. The course is likely to be of most interest to students outside of the Microelectronics and Nanotechnology Area.

Course Enrollment History: Spring 2021 – 6, Fall 2021 – 9, Spring 2022 – 15, Spring 2023 – 31, Spring 2024 - 29

T. S. Mth

Mithuna Thottethodi,
Associate Head for Teaching and Learning
Elmore Family School of Electrical and Computer Engineering

Course Information

- **ECE 50642, Essentials of Transistors, Spring 2024**
- **CRNs:**

On-campus	26471 - 36
Online	18886 - EP5

- **Run dates:** 2/12-3/24/2024
- **Instructional Modality:** Asynchronous online; this course has no required in-person sessions.
- **Course credit hours:** 1
- **Prerequisites:** A basic knowledge of undergraduate semiconductor device course (e.g., energy bands, doping, carrier densities, drift-diffusion equations, Fermi and quasi-Fermi levels, etc.) is assumed. No familiarity with electronics or transistors is assumed, but those with such a background will gain an understanding of how nanoscale transistors differ from their micrometer scale cousins.

Instructor Contact Information

- **Note:** The course lectures were pre-recorded by Prof. Mark Lundstrom. During Spring 2022, this course will be facilitated by Assistant Professor Dallas Morisette.
- **Name of the instructor:** Dallas Morisette, Research Assistant Professor of Electrical and Computer Engineering, Purdue University
    - **Purdue Email Address:** morisett@purdue.edu
- **Instructor in lecture videos:** Mark S. Lundstrom, Don and Carol Scifres Distinguished Professor of Electrical and Computer Engineering; National Academy of Engineering member
- **Office hours:** See the Brightspace course for office hours information.

Course Description

The transistor has been called the greatest invention of the 20th century – it enabled the electronics systems that have shaped the world we live in. This course is designed for anyone seeking a sound, physical, intuitive understanding of how modern transistors operate. Important technology considerations and applications of transistors are also discussed. The focus is on MOSFETs, but other types of transistors are briefly considered too. The course is broadly accessible to students with only a very basic knowledge of semiconductor physics and electronic circuits and should be useful for advanced undergraduates, beginning graduate students, as well as practicing engineers and scientists.

Learning Resources, Technology & Texts

There are no required textbooks for this course.

A draft copy of a set of lecture notes published by World Scientific is provided in Brightspace:

- *Fundamentals of Transistors* by Mark Lundstrom (PDF) (copyright World Scientific Publishing Company, 2018).
- *Recommended Reading Guide* for *Fundamentals of Transistors*

Those who wish to dive deeper may consult the following, linked in Brightspace:

- *Compact Models and the Physics of Nanoscale FETs,* IEEE Trans. Electron Devices, vol. 61, pp. 225-233, by Mark S. Lundstrom and Dimitri A. Antoniadis, 2004. (PDF)

Learning Outcomes

After completing this course, you will be able to:

- Understand MOSFET IV characteristics and device metrics and be able to analyze measured transistors characteristics and extract key device parameters.
- Have a sound understanding of the physical operation of transistors and be acquainted with the traditional theory of the MOSFET.
- Be familiar with 1D/2D/3D MOS electrostatics and appreciate the need for advanced MOSFET structures such as the FinFET.
- Understand modern transport theory (the transmission approach) and its application to nanoscale MOSFETs.
- Be introduced to other barrier-controlled transistors, such as HEMTs and bipolar transistors.
- Know what a physics-based compact model is and the role they play in electronics.

Assignments

Your grade in this course is based on your performance on the following criteria:

Assessment	Description	% of Final Grade
Quizzes	Multiple choice quizzes on lecture topics	30%
Exam 1	Proctored & timed exam	35%
Exam 2	Proctored & timed exam	35%

Additional information on course activities:

- **Lectures:** All lectures are available immediately.
- **Short Problems (ungraded)**
    - A short problem is provided after most lectures.
    - You should be able to quickly work these problems after understanding the lecture.
    - These problems are not graded, but solutions will be posted.
    - You are encouraged to discuss the problems and solutions with your classmates in the discussion forum.

- **Homework (ungraded)**
  - The homework provided in this course is for your information and practice.
  - Solutions to homework are posted for your convenience.
- **Practice Exams (ungraded)**
  - There are 2 practice exams.
  - The best way to prepare for exams is to be familiar with the homework problems, the short problems, and the practice exams.
  - You are encouraged to complete the assessments before viewing the solutions.
  - The practice exams are not graded.
- **Quizzes (graded)**
  - Multiple-choice quizzes will follow most lectures to assess your understanding of the material.
  - Lecture quizzes are timed.
  - These questions will be worth 30% of your course grade.
- **Exams (graded)**
  - There are two (2) proctored exams.
  - Each exam is worth 35% of your course grade.
  - Each exam is available for 72 hours.
  - Exams are designed to be completed in 50 minutes. You will have 60 minutes to complete each exam and submit your answer sheet to Gradescope.
  - The timer cannot be paused.
  - Exams are closed book, closed notes.
  - A calculator is required; a scientific calculator without online/internet capabilities may be used during exams.
  - A formula sheet and answer sheet will be provided. These will need to be printed before beginning the exams.

Grading Scale

A	> 90%
B	80% - 89%
C	70% - 79%
D	60% - 69%
F	<60%

Discussion Guidelines

Please follow the Discussion Guidelines when contributing to discussions in this course. Here are a few of the key points you should remember:

- Do not use offensive language. Present ideas appropriately.

- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an “open-mind” and be willing to express even your minority opinion.
- Make substantive posts or comments. Avoid comments that do not contribute to the discussion, like "thanks" or "good post."
- Do not hesitate to ask for feedback.
- Be concise and to the point. Give other students the opportunity to join in the discussion.
- Think and edit before you push the “Send” button.

Course Schedule

Week/Date	Tasks to Complete	Due Dates

1
Feb 14- 20
	Transistors & Circuits
	• Review syllabus
	• View Lectures L1.1 – L1.6
	• Complete:
	  • L1.1 – L1.5 Short Problems
	  • L1.1 – L1.5 Quizzes
	  • Unit 1 Homework
		Examity Practice Quiz:
		Due: Sunday, February 20, 11:59 PM ET (2/21, 04:59 UTC)
		Week 1: Lecture Quizzes
		Due: Friday, February 18, 8:00 AM ET (13:00 UTC)

2
Feb 21-27
	Essential Physics of the MOSFET
	• View Lectures L2.1 – L2.6
	• Complete:
	  • L2.1 – L2.5 Short Problems
	  • L2.1 – L2.5 Quizzes
	  • Unit 2 Homework
	  • Practice Exam 1
	  • Proctored Exam 1
		Week 2: Lecture Quizzes
		Due: Friday, February 25, 8:00 AM ET (13:00 UTC)
		Proctored Exam 1:
		• Opens: Friday, February 25, 8:00 AM ET (13:00 UTC)
		• Due: Sunday, February 27, 8:00 AM ET (13:00 UTC)

3
Feb 28-Mar 6
	MOS Electrostatics
	• View lectures L3.1 – L3.10
	• Complete:
	  • L3.1 – L3.9 Short Problems
	  • L3.1 – L3.9 Quizzes
	  • Unit 3 Homework
		Week 3: Lecture Quizzes
		Due: Friday, March 4, 8:00 AM ET (13:00 UTC)

4
Mar 7-13
	Transmission Theory of the MOSFET
	• View lectures L4.1 – L4.8
	• Complete:
	  • L4.1 – L4.7 Short Problems
	  • L4.1 – L4.7 Quizzes
	  • Unit 4 Homework
		Week 4: Lecture Quizzes
		Due: Friday, March 11, 8:00 AM ET (13:00 UTC)

Mar 14-19	**Spring Break**	No tasks

5
Mar 21-Apr 3
	Additional Topics
	• View lectures L5.1 – L5.7
	• Complete:
	  • L5.1 – L5.6 Short Problems
	  • L5.1 – L5.6 Quizzes
	  • Unit 5 Homework
	  • Practice Exam2
	  • Proctored Exam 2
		Week 5: Lecture Quizzes
		Due: Friday, March 25, 8:00 AM ET (12:00 UTC)
		Proctored Exam 2:
		• Opens: Thursday, March 31, 8:00 AM ET (12:00 UTC)
		• Due: Saturday, April 2, 11:59 PM ET (4/3, 03:59 UTC)

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under University Policies.

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack**.** Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on

weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Additional Wellness Resources

TaskHuman offers private, real-time, on-demand, 1-on-1 video calls with wellness coaches covering over 800+ topics such as anxiety, mindfulness, reducing stress, clean eating, time management, in- home workouts, relationship tensions, financial issues, spiritual guidance and many more. You can access these wellness coaches from around the world 24/7. The College of Engineering has an exclusive agreement with TaskHuman which gives you **FREE and UNLIMITED** access to these resources. Over 3,200 calls have been made by College of Engineering people so far with an average satisfaction rating of 4.89/5.

Learn more here: https://engineering.purdue.edu/ECE/TaskHuman.

To download TaskHuman:

1. Scan the QR Code to download the TaskHuman App or download the TaskHumanApp directly from the App Store or Google Play Store.
2. Create an account.
3. Go to **Settings** and tap **Check for Discounts**.
4. Insert your code: **purdue63**

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it related to COVID-19, students may submit requests for emergency assistance from the Critical Needs Fund.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.