ECE 305: Fall 2016
Course Introduction

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electron devices

vacuum tube
Edison effect, 1880
J.J. Thompson, 1897
diode (Fleming, 1904)
triode (De Forest, 1905)

transistor
Bardeen, Brattain,
Shockley, 1947

integrated circuit
Kilby /Noyce, 1958

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electron devices

modern solar cell
Chapin, Pearson, Fuller, 1954

LED
Holonyak, 1962

semiconductor laser
Hall, 1962
Purdue’s semiconductor history

“Karl Lark-Horovitz is best known for turning the physics department of Purdue University, then a backwater school, into a research powerhouse. His personal research was in germanium and solid state science -- and if anyone had had a chance of inventing the transistor before Bell, it was Lark-Horovitz. As it was, the Purdue physics lab was probably only six to twelve months behind.”

http://www.pbs.org/transistor/album1/addlbios/lark.html

1941: WWII: Semiconductor diode rectifiers
http://www.computerhistory.org
"The transistor was probably the most important invention of the 20th Century, and the story behind the invention is one of clashing egos and top secret research."

- Ira Flatow, Transistorized!

http://www.pbs.org/transistor/
transistors

symbol

switch

amplifier

input signal

output signal

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real transistors

source drain SiO$_2$ silicon channel ~ 20 nm
gate oxide SiON ~ 1.1 nm
gate electrode
channel ~ 20 nm

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transistor IV

symbol

![Graph showing the IV characteristics of a transistor with different bias voltages on the drain.]
“Moore’s Law”

$L = 5000 \text{ nm}$  
Micro-electronics

$5000 \text{ nm} \rightarrow 5 \text{ nm}$  
Nano-electronics

$L = 5 \text{ nm}$ ?
exponential growth

![Graph showing exponential growth of transistors per CPU chip from 1974 to 2010. The x-axis represents the year, and the y-axis represents billions of transistors. The graph has a logarithmic scale on the y-axis, with data points indicating a steep rise in transistor count over time.]
21st Century electronics

CMOS transistors for logic
III-V transistors for RF
A/D and D/A converters
Digital Signal processor
Microprocessor
ROM and FLASH memory

CMOS imager
Gyroscope
MEMS devices
Magnetometer
Microphone, speaker
LCD display and touch screen

www.apple.com
“If someone from the 1950’s suddenly appeared today, what would be the most difficult thing to explain to them about today?”
most popular answer

“I possess a device in my pocket that is capable of assessing the entirety of information known to humankind.

I use it to look at pictures of cats and get into arguments with strangers.”
21st Century electronics

Bell Labs 1947

Apple 2007

21st Century electronics
“The end of Moore’s Law?”
Semiconductor Industry Status: July 2016

14 nm technology (in production)
10 nm (productizing; scheduled for end of 2016)
7 nm (integrating)
5 nm (research)

Biggest concern: energy dissipation.

Biggest source of energy dissipation: moving data in and out of memory.

Need a fundamentally better transistor, but it is really hard to find one.
Electronics beyond Moore’s Law

More-than-Moore: Gene sequencing

Cost per Raw Megabase of DNA Sequence

http://www.genome.gov/sequencingcosts/
Within the US automotive and electrical equipment industries, robotic price/performance is better than or near parity with manual labor costs.

<table>
<thead>
<tr>
<th>US automotive industry</th>
<th>US electrical equipment industry</th>
<th>US furniture industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 industrial robot shipments (units)</td>
<td>2013 industrial robot shipments (units)</td>
<td>2013 industrial robot shipments³ (units)</td>
</tr>
<tr>
<td>10,320</td>
<td>3,328</td>
<td>23</td>
</tr>
</tbody>
</table>

Price/performance-adjusted nominal wages and operating cost ($/hour)

Source: Boston Consulting Group, “The Shifting Economics of Global Manufacturing” (February 2015)
21st Century electronics

Bell Labs 1947

Apple 2007

21st Century electronics
course text

Semiconductor Device Fundamentals, 2nd Edition (SDF)  
Course objectives: To introduce students to the fundamentals of semiconductors and semiconductor devices.

Part 1: Semiconductor Materials: 3 weeks
Part 2: PN diodes and Photovoltaics 3 weeks
Part 3: MS / Schottky diodes 3 weeks
Part 4: MOS / MOSFET devices 3 weeks
Part 5: Bipolar Junction Transistors 3 weeks
course objectives

i. To predict the observable properties of semiconductors as a function of various parameters

ii. To design pn diodes suitable for current rectification and solar power production

iii. To predict the behavior and limitations of Schottky diodes

iv. To evaluate the design and performance of metal-oxide-semiconductor field effect transistors (MOSFETs)

v. To describe, predict, and improve the behavior of bipolar junction transistors (BJTs)
grading

550 total course points

**Homework due in class on dates listed on syllabus.**
Will be posted 1 week before (maximum of 100 points)

**In-class assignments and quizzes** (maximum of 50 points):
Sometimes on paper, more often with iClicker

5 exams (4 in class + final, maximum of 100 points each)

**Total score:** The sum of the highest 4 exams, assuming you took Exam 5, plus your HW, plus in-class bonus points. If you don’t take Exam 5, it counts as a zero.

**Letter grade:** Will divide total score by 500, and assign letter grades on a 10-point scale
frequent exams

1) Multiple choice (5 questions) 40 points
2) Problem 1 (usually 30 points)
3) Problem 2 (usually 30 points)
How Tests Make Us Smarter

JULY 18, 2014

Gray Matter

By HENRY L. ROEDIGER III

TESTS have a bad reputation in education circles these days: They take time, the critics say, put students under pressure and, in the case of standardized testing, crowd out other educational priorities. But the truth is that, used properly, testing as part of an educational routine provides an important tool not just to measure learning, but to promote it.

In one study I published with Jeffrey D. Karpicke, a psychologist at Purdue, we assessed how well students remembered material they had read. After an initial reading, students were tested on some passages by being given a blank sheet of paper and asked to recall as much as possible. They recalled about 70
course web page

All course information is posted on the class home page

http://nanohub.org/groups/ece305bermel

Class announcements will supersede prior written information and will be posted on the course homepage

Campus Emergency Policies: 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. Information about changes will be posted on the course web page and available from pbermel@purdue.edu

8/22/2016
To report an emergency, call 911. To obtain updates regarding an ongoing emergency, sign up for Purdue Alert text messages, view www.purdue.edu/ea.

There are nearly 300 Emergency Telephones outdoors across campus and in parking garages that connect directly to the PUPD. If you feel threatened or need help, push the button and you will be connected immediately.

If we hear a fire alarm during class we will immediately suspend class, evacuate the building, and proceed outdoors. Do not use the elevator.

If we are notified during class of a Shelter in Place requirement for a tornado warning, we will suspend class and shelter.

If we are notified during class of a Shelter in Place requirement for a hazardous materials release, or a civil disturbance, including a shooting or other use of weapons, we will suspend class and shelter in the classroom, shutting the door and turning off the lights.

cheating

It’s wrong. I have a zero tolerance policy. Any case of cheating will earn you an F in the course and a report to the Dean of Students.

------------------------- Exam Integrity Statement -------------------------

If I am caught cheating on this exam, I will earn an F for the course and be reported to the Dean of Students.
Write out the above statement:

Signature: ______________________________________________

8/22/2016 Bermel ECE 305-Fall 2016
getting help

Instructor Office Hours: MWF, 4:20-5:20 PM, EE 332

TA (Yubo Sun, sun73) Office Hours held in EE 209
- Wednesday, August 24: 1-3 pm
- Friday, August 26: 1-3 pm
- Monday, August 29: 10 am - noon
- Wednesday, August 31: 1-3 pm
- Friday, September 2: 1-3 pm
- All Wednesdays, starting September 7: noon-3 pm
- All Mondays starting on September 12: 10 am - 1 pm

Help from Piazza: [http://piazza.com/purdue/fall2016/ece305/home](http://piazza.com/purdue/fall2016/ece305/home)
summary

- We’re going to learn the fundamental science and engineering behind the modern electronics that underpin our lives today!

- The course will be taught with clear, detailed notes, frequent in-class activities, weekly homework assignments utilizing online tools, and five exams (four in-class, and one during finals week)

- The majority of course points (400) will come from exams; however homework (100) and in-class assignments (50) will be needed to get above a C

- Questions can be addressed through course website, Piazza, TA, or professor office hours