ECE 305: Fall 2015
Course Introduction

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course objectives

To introduce the fundamentals of semiconductors and semiconductor devices.
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
electron devices

modern solar cell

LED

semiconductor laser

Chapin, Pearson, Fuller, 1954

Holonyak, 1962

Hall, 1962

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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
transistors

"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
real transistors

symbol

\[ \text{source} \quad \text{gate} \quad \text{drain} \]

\[ \text{silicon} \]

\[ \text{SiO}_2 \]

\[ \text{SiON} \sim 1.1 \text{ nm} \]

\[ \text{gate oxide} \]

\[ \text{channel} \sim 20 \text{ nm} \]

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transistor IV

symbol

\[ \text{symbol} \]

\[ \begin{array}{c}
G \\
\hline \\
\hline \\
\hline \\
D \\
\hline \\
\hline \\
\hline \\
S
\end{array} \]

\[ \text{L} = 100 \text{ nm} \]

\[ \begin{array}{c}
0 \\
0.2 \\
0.4 \\
0.6 \\
0.8 \\
1
\end{array} \]

\[ \begin{array}{c}
0 \\
200 \\
400 \\
600 \\
800 \\
1000 \\
1200
\end{array} \]

\[ I_D (\mu A/\mu m) \]

\[ V_{DS} (V) \]
“The most important moment since humankind emerged as a life form.”

Isaac Asimov

(speaking about the “planar process” used to manufacture ICs - - invented by Jean Hoerni, Fairchild Semiconductor, 1959).

IEEE Spectrum Dec. 2007
“Moore’s Law”

$L = 5000 \text{ nm}$

$5000 \text{ nm} \rightarrow 5 \text{ nm}$

$L = 5 \text{ nm} ?$

Micro-electronics
exponential growth

Transistors per cpu chip

Billions of transistors

Year


1974
21st Century electronics

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

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

Intel: July 2015

14 nm technology (in production)
10 nm (productizing)
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.
More-than-Moore: Gene sequencing

http://www.genome.gov/sequencingcosts/
Electronics beyond Moore’s Law

Ion Torrent (Nature, 475, 349, 21 July, 2011)
Google contact lens

L is for Life Sciences: Google's contact lens maker will be its own company

A tiny chip and antenna are built into a prototype smart contact lens under development by Google X. Credit: Google

21st Century electronics

Bell Labs 1947

Apple 2007

21st Century electronics
Course objectives: To introduce students to the fundamentals of semiconductors and semiconductor devices.

Part 1: Semiconductor Fundamentals: 5 weeks
Part 2: PN diodes, MS diodes, and devices 5 weeks
Part 3: Transistors 5 weeks
course text

Semiconductor Device Fundamentals, 2nd Edition (SDF)  
ISBN-0-201-54393-1
grading

550 total course points

Homework assigned Monday. Due Thursday. Solutions posted Friday (maximum of 100 points)

In-class quizzes (maximum of 50 points)

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

Total score: The sum of the highest 3 of exams 1-4 and exam 5 plus your HW plus your quiz total.

You must take Exam 5.
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
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
ABET outcomes

(i) An understanding of the semiconductor bonding and energy band models, of semiconductor carrier properties and statistics, and of carrier action.

(ii) An ability to apply standard device models to explain/calculate critical internal parameters and standard terminal characteristics of the pn-junction diode and the Schottky diode

(iii) An ability to apply standard device models to explain/calculate critical internal parameters and standard terminal characteristics of the Metal-Oxide-Semiconductor Field Effect Transistor and the Bipolar Junction Transistor

Assessment:
Exam 1 will assess outcome (i), exams 2 and 3 will assess outcome (ii), and exams 4 and 5 will assess outcome (iii).
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: ____________________________________________
questions
Google Official: on “ideal recruits”

"There is no single set of discrete skills one can learn that will last an entire career in high-tech," Johnson writes. Instead, "ideal recruits are creative, adaptable and autonomous, and they have achieved a deep understanding of core subjects such as math, physics and computer science that make it possible to have a razor-sharp intuition and an ability to assimilate new subjects and technologies quickly, without even the expectation of being trained; they train themselves on the skills du jour as the need arises and with minimum help or structure."

Bruce Johnson, the Atlanta site and engineering director for Google, in the Atlanta Journal-Constitution (12/23/11).
How to study

1) Do the assigned reading **before class**
2) Attend class **and** pay attention
3) Review the lecture after class
4) Do the HW without looking at the solutions
5) Review and understand the solutions
6) Be sure you understand the quizzes
7) Ask questions
Consider signing an “Honors contract” for ECE 305
you’re in training

“I hated every minute of training, but I said, 'Don't quit. Suffer now and live the rest of your life as a champion.’”
-Muhammad Ali

"Stay in College, get the knowledge, stay there until you are through. If they can make penicillin out of moldy bread, they can sure make something of you!"

-Muhammad Ali

http://www.brainyquote.com/quotes/quotes/m/muhammadali148629.html
ECE 305

Work hard, have fun, learn something you can use for the rest of your career.

Get started now!

https://nanohub.org/groups/ece305bermel