Spring 2019 Purdue University

ECE 255: L1 Introduction to Electronic Analysis and Design

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ECE 255 is about:

Electronics circuits with “active” devices (transistors) that can amplify and transform signals (e.g. to compute and communicate).

ECE 255 uses concepts from 201 (e.g. KCL, KVL, Thevinin equiv, etc.).

The course is also about some **more general ideas**, such as linearizing nonlinear problems, modeling a complex device with an equivalent circuit, using CAD tools, solving open-ended problems, etc.

Electron devices

The modern world has been shaped by communication and computing systems.

Electron devices make these systems possible.

20th Century electronics was transformed by **microelectronic devices** and integrated circuits.

The 21th Century will be shaped by **nanoelectronic** devices and integrated nanosystems.

Key dates in electron devices

1904/05: Vacuum tubes: radio communication

1947: Transistors: communications and computing

1959: Integrated circuits

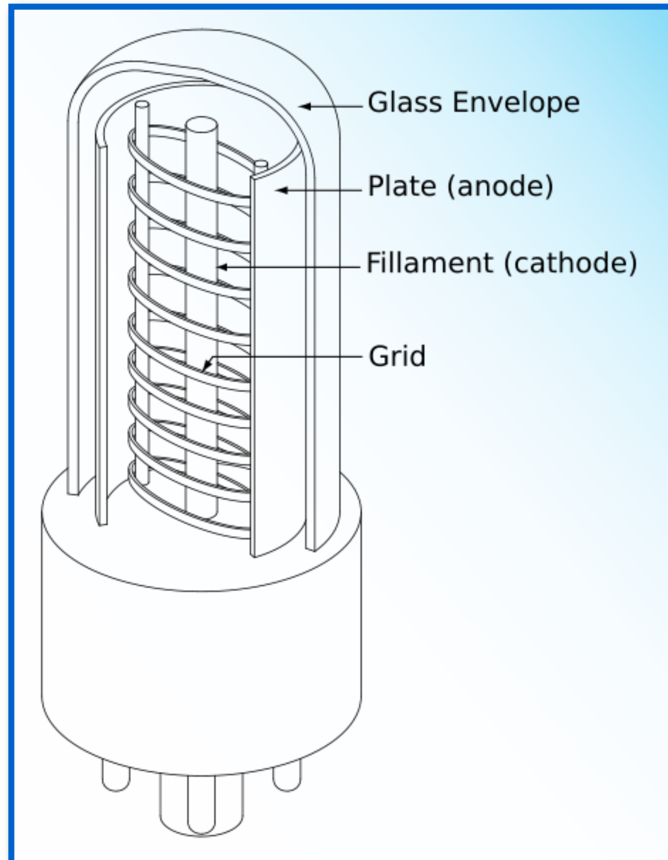
1962: LED’s and semiconductor lasers

1965: Moore’s Law era

2015: → Beyond Moore’s Law

Vacuum tube electronics

Vacuum Tube



http://en.wikipedia.org/wiki/Vacuum_tube

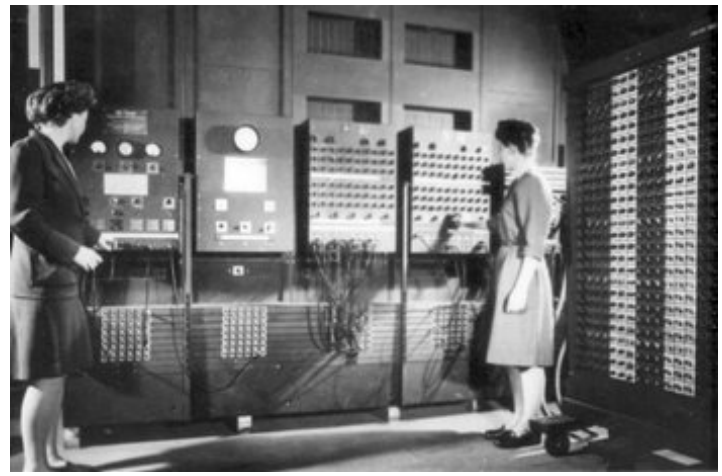
Edison effect (Edison, 1883)
cathode rays (Thompson, 1897)
diode (Fleming, 1904)
triode (De Forest, 1905)

Vacuum tube electronics

Golden age of radio
1935 - 1950

http://history.sandiego.edu/GEN/recording/images5/radio11.jpg

ENIAC
(1945, Mauchly and Echkert, U Penn)

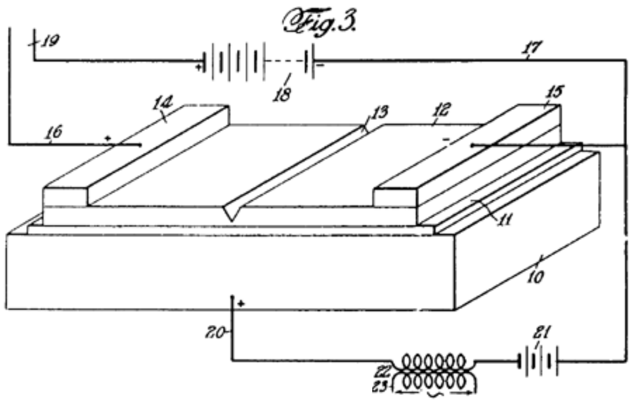


http://en.wikipedia.org

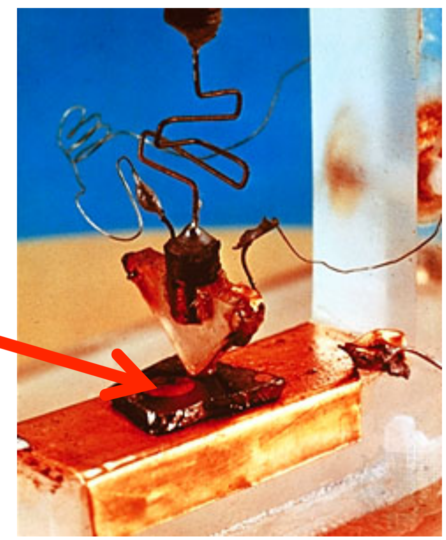
17,468 vacuum tubes
1000 sq. feet of floor space
30 tons
150 KW
~50 vacuum tubes / day

Invention of the transistor

Field-Effect Transistor
Lillienfield, 1925
Heil. 1935



Bardeen, Schockley,
and Brattain, 1947



Lucent / Bell Labs

"The transistor was probably the most important invention of the 20th century,"

Ira Flatow, Transistorized!
www.pbs.org/transistor

Semiconductor history: Purdue

1941: WWII: Semiconductor diode rectifiers

http://www.computerhistory.org

"Karl Lark-Horovitz is best known for turning the physics department of Purdue University, then a backwater school, into a research powerhouse.

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

Impact of transistors

transistors

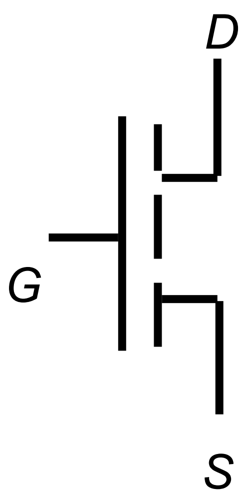
“discrete electronics”

Sony TR-63
6-transistor
shirt pocket radio
1957

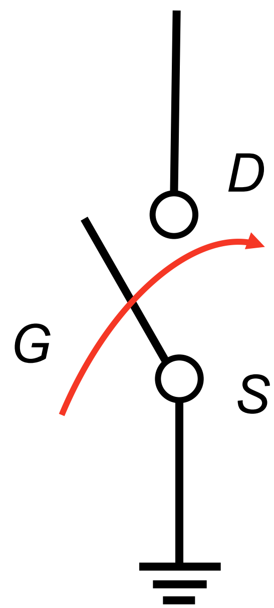
http://www.sony.net/Fun/SH/1-6/h2.html

Applications of transistors

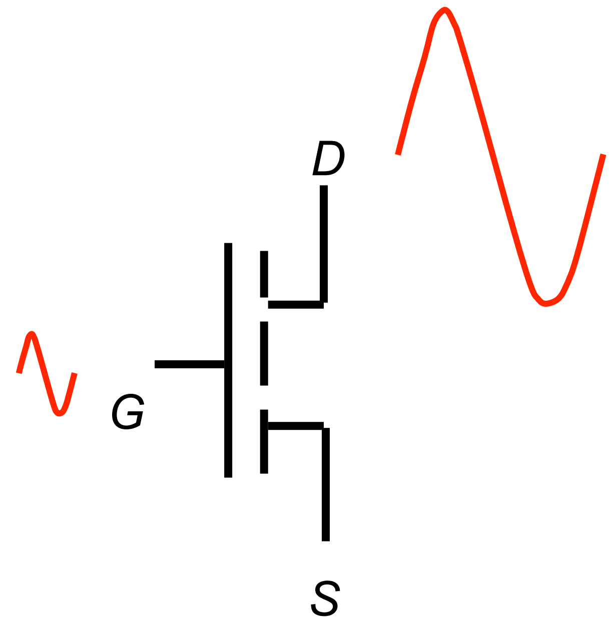
symbol



switch



amplifier



digital electronics

analog electronics

Even more important than transistors...

"The most important moment since mankind emerged as a life form."

Isaac Asimov

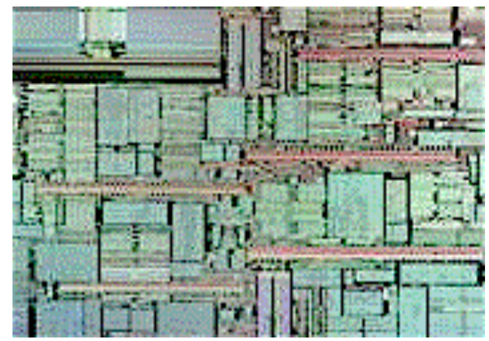
invention of the integrated circuit

integrated circuit

Kilby and Noyce (1958, 1959)

"Integrated electronics"
not discrete electronics

Intel 4004

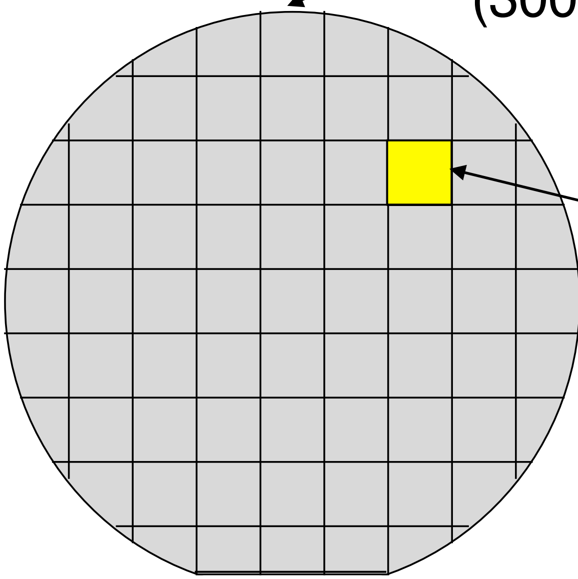


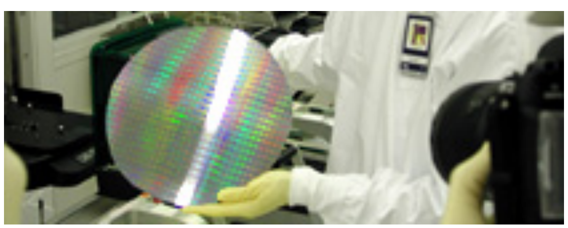
Hoff and Faggin (1971)

~2200 transistors

Microelectronics

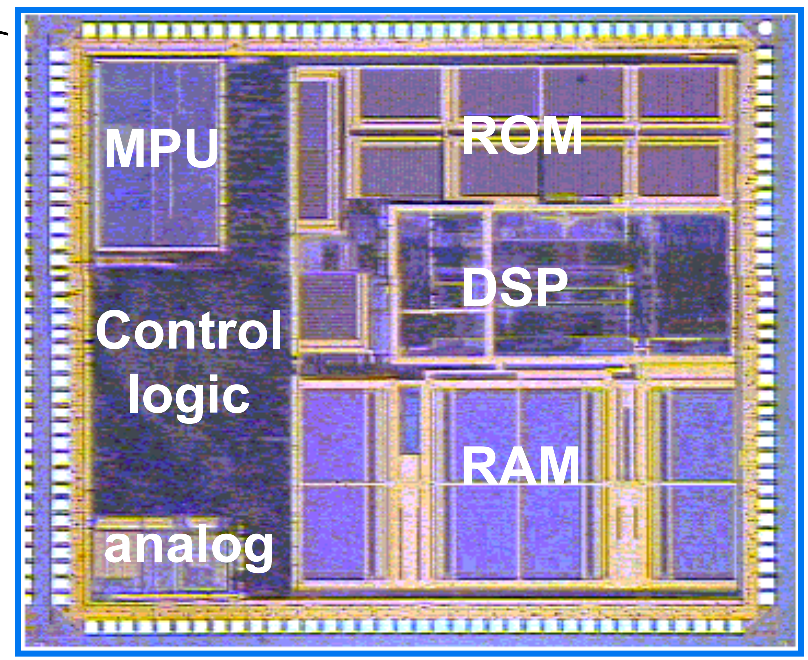
Silicon wafer
(300 mm)





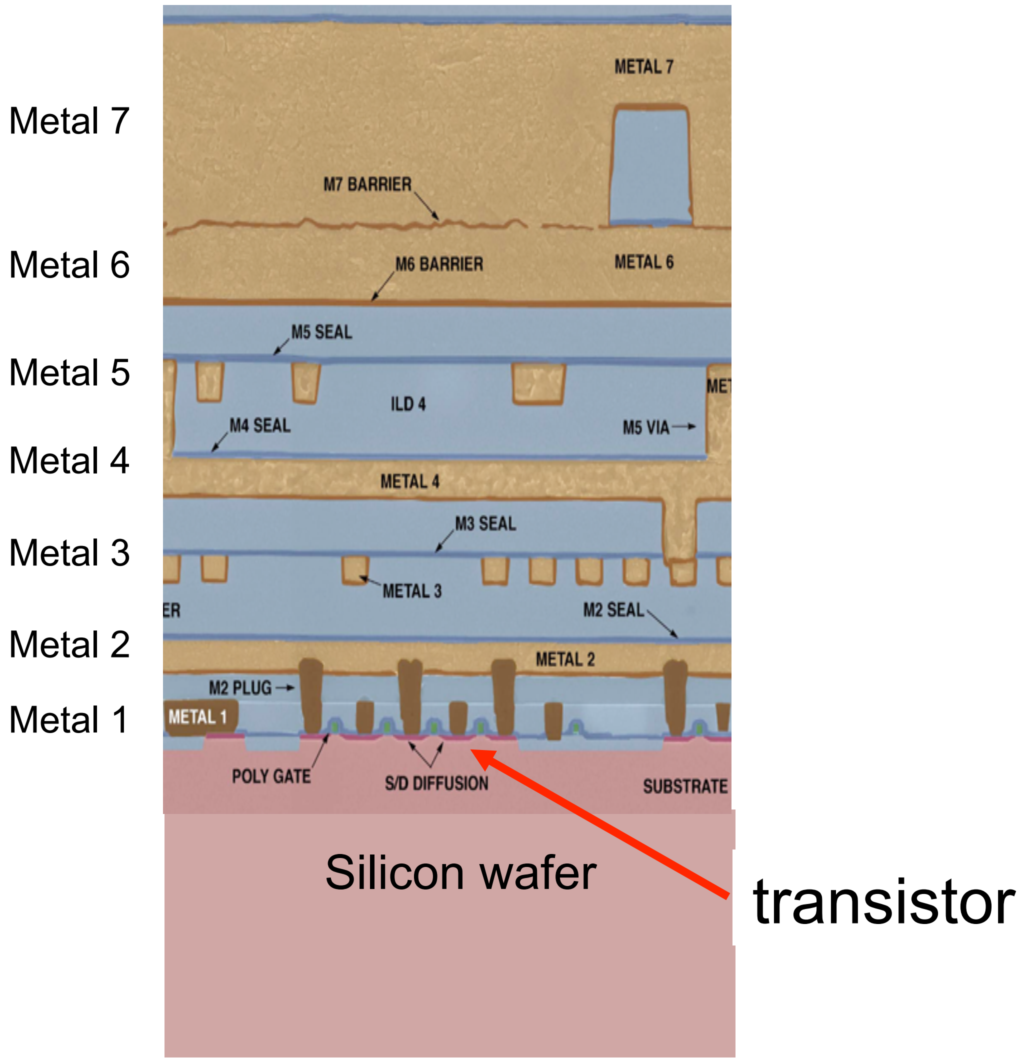
Intel

Silicon “chip”
(~ 2 cm x 2 cm)



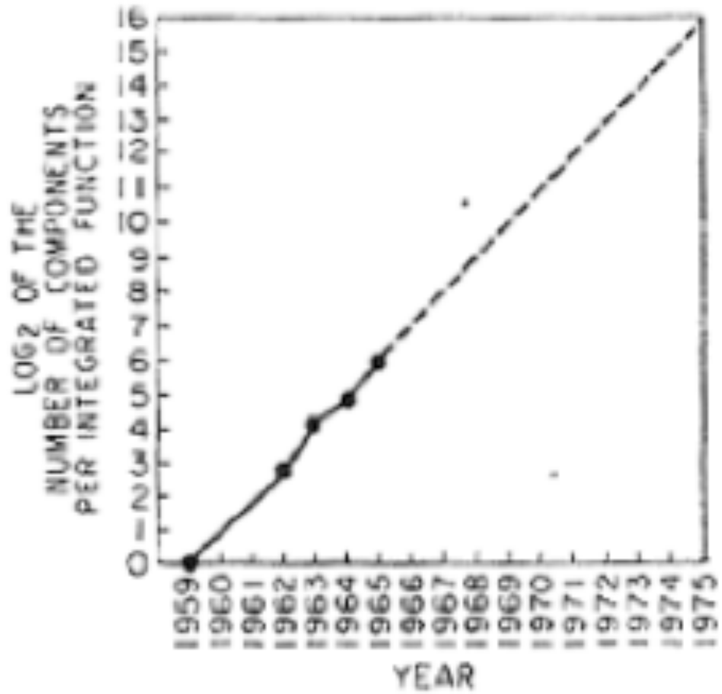
TI cell phone chip

Cross section of a chip



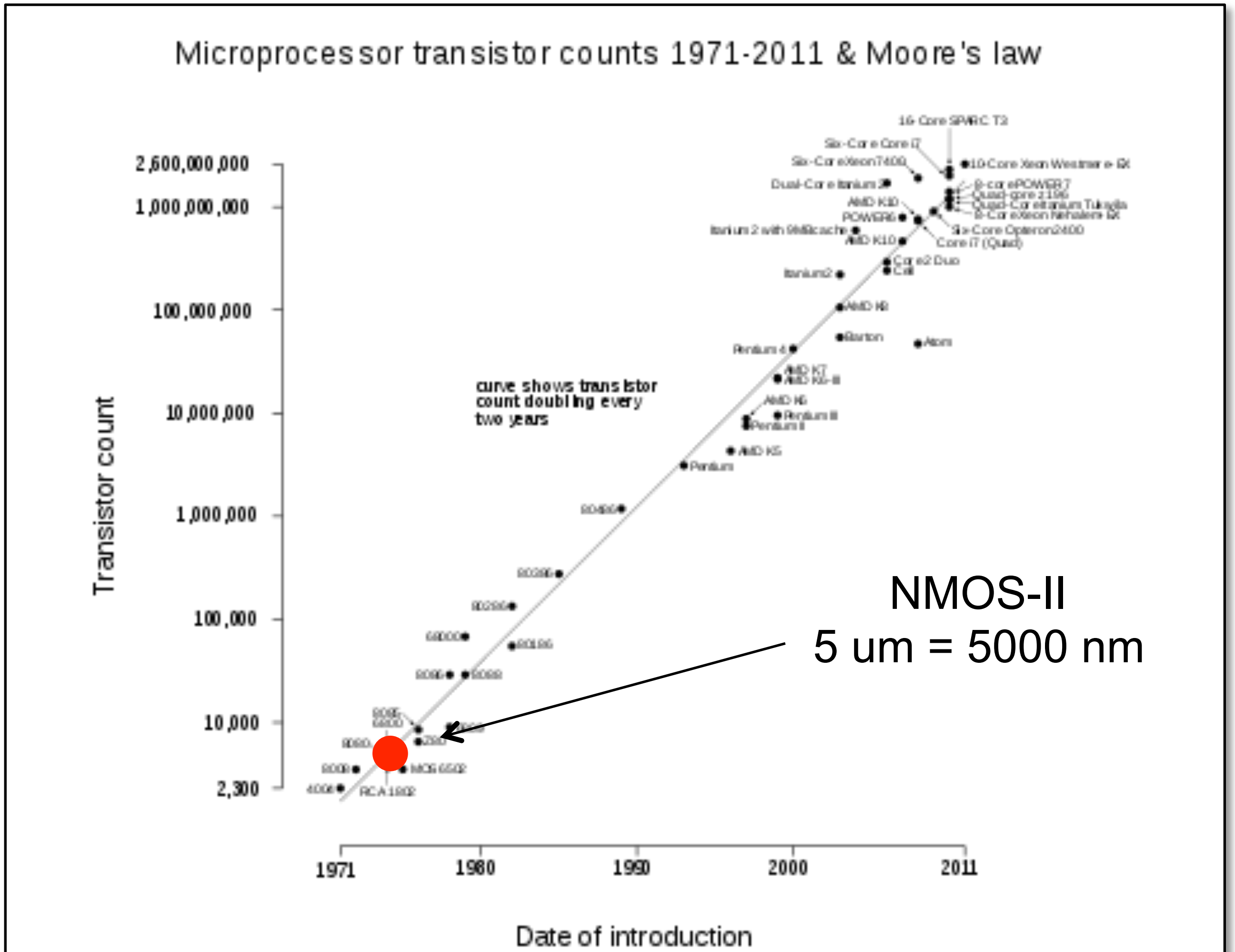
Moore's Law

Gordon E. Moore
Co-founder, Intel Corporation



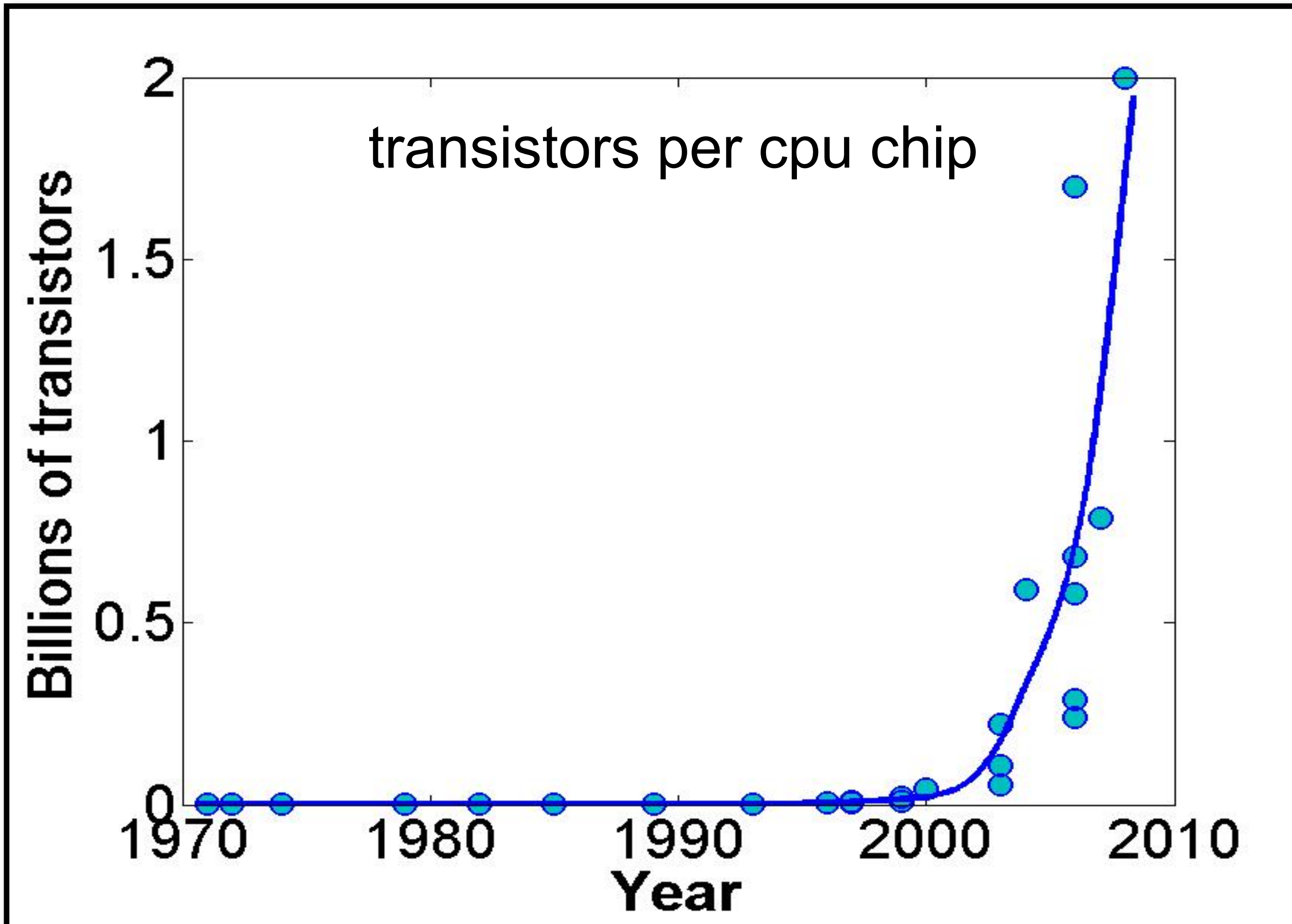
Electronics, vol. 38, April 19,1965

Moore's Law continues



more transistors per chip means:
higher performance / lower cost / better reliability

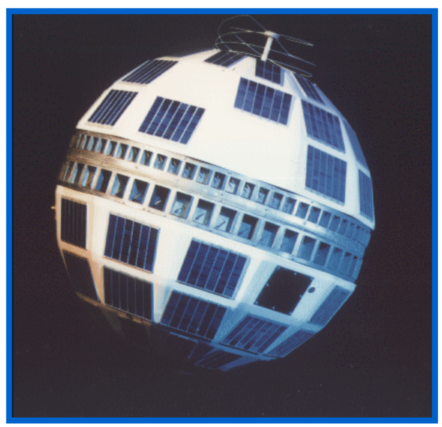
Moore's Law on a linear plot



Impact of integrated circuits

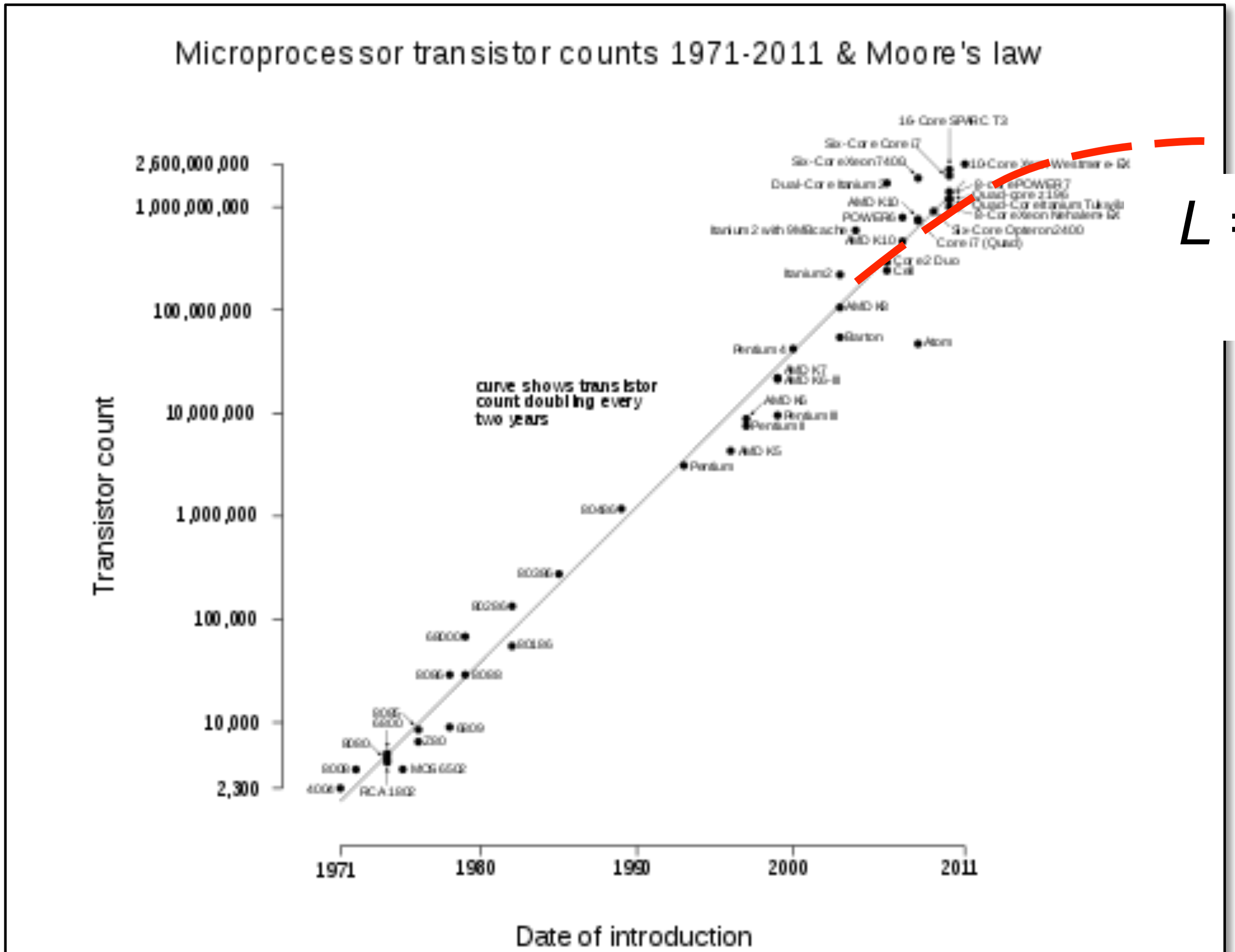
Smartphones

Personal Computers



communication satellites

The end of Moore's Law



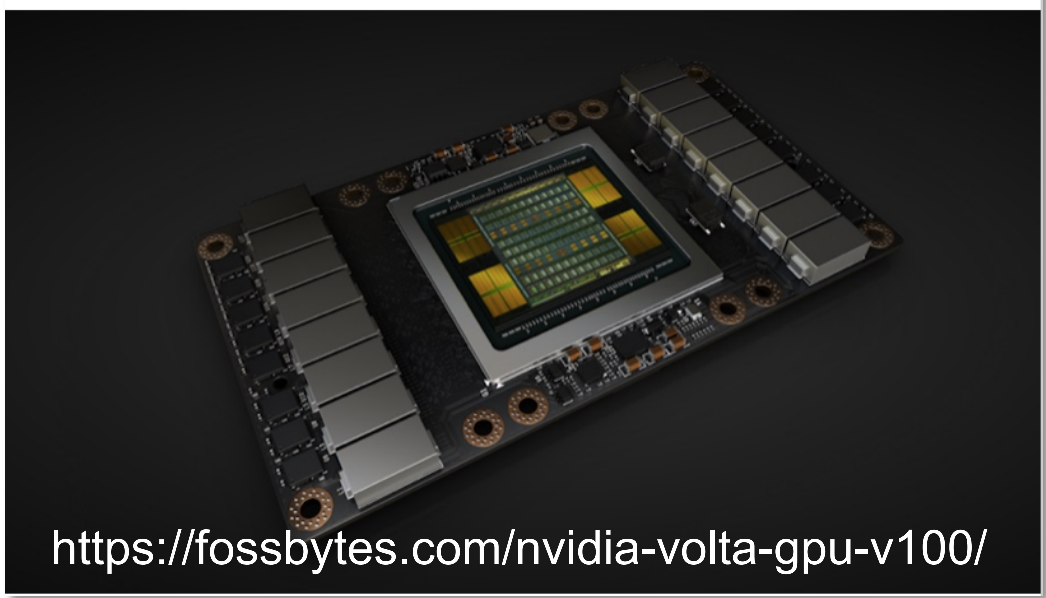
L = 5 nm
3 nm?

more transistors per chip means:
higher performance / lower cost / better reliability

Beyond Moore's Law

Nvidia Volta GPU Has 21 Billion Transistors And 5,120 Cores — "You Can't Make A Chip Any Bigger"

May 11, 2017



Nvidia is a "fabless" company

The Next 25 Years in Electronics

International Electron Devices Meeting
San Francisco, CA Dec. 2018

About ECE 255

255 is about electronic circuits with transistors − discrete **and** integrated, mostly analog, not digital.

This semester, we’ll spend a little more time on semiconductors than in the past.

Course description

This course is an introduction to electronic circuits. It **applies concepts from EE-201 to circuits with active devices (transistors)**. The important concept of an equivalent circuit model is stressed, and **students are introduced to silicon microelectronics.** In addition to analysis of electronic circuits, the course stresses design, solving open-ended problems and the use of computer tools in the design process.

TEXT: *Microelectronic Circuits*, 7th Ed., Adel S. Sedra and Kenneth C. Smith, 2015.

Brief course outline

1-3 Brief look at semiconductors. Diodes and the concepts of mathematical and equivalent circuit models. Applications of models to circuit analysis and design. Introduction to the Spice computer program.

4-6 DC models for bipolar junction transistors (BJTs) and MOSFETs.

7-10 Small signal models and single-stage amplifiers.

11-13 Multi-stage amplifiers.

14-15 Low and High frequency response.

Outcomes:

More important that the specific outcomes listed are the more general concepts that you will be introduced to:

Linearizing nonlinear problems
Modeling complex devices with equivalent circuits
Using CAD tools
The difference between design and analysis

2 stage CMOS op amp

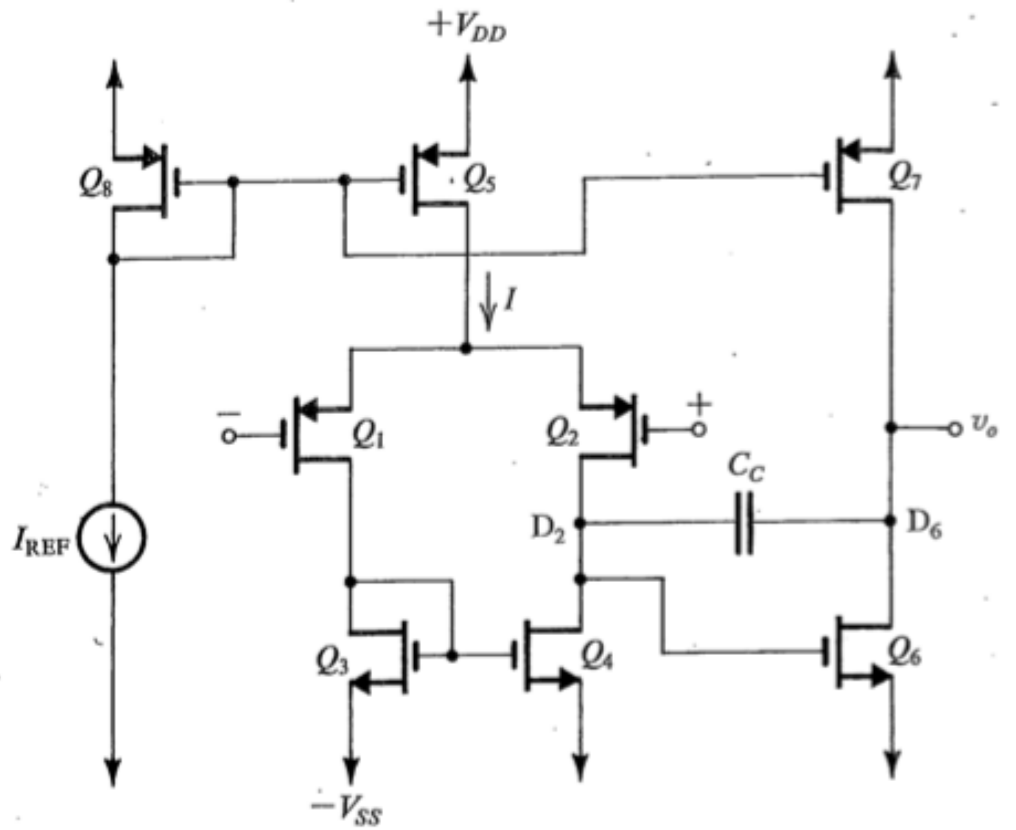


Fig. 9.40, Sedra and Smith, 7th Ed., 2015.

Grading

Exam #1	20% (02/09) 6:30 PM :LIILY 1105
Exam #2	20% (03/05) PHYS 112
Exam #3	20% (04/02) PHYS 112
Final:	20%, TBA
Homework	5%
In class exercises:	5%
SPICE Projects:	10%

All exams are closed book closed notes. The **only calculator** allowed in the exam is the TI-30X IIS (available at University Book Store or Follett)

Getting help

Prof. Lundstrom: MWF 3:30 – 4:30 Wang 3055
(or by appt. lundstro@purdue.edu)

TEACHING ASSISTANTS:

Rayane Chatrieux rchatrie@purdue.edu
Aman Maskay maskay@purdue.edu

HELP / STUDY ROOM FOR ECE 255 – MSEE 180

Course policies

- **Come to class on time.**

- **NO DEVICES** (e.g. cell phones, laptops). Come to focus on ECE-255.

- **No late homework will be accepted.**

- An **incomplete grade** is only for students who do most of the required work and at the end of the semester due to a well-documented emergency cannot finish the course.

- **No make-up exams will be given.**

Course policies

- Only in **well-documented emergency situations** will I allow a student to take the exam at a different time, no other excuses are accepted. Hunting, fishing, family reunions, fraternity events are not considered emergencies.

- You cannot do extra work after the semester is over to change your grade. **All grades are FINAL once submitted.**

- If you have any issue or difficulty with the course, **contact me** during the semester and seek help in advance.

Attendance

You should attend class because you will do better in ECE-255 if you do.

The only way to receive credit for **the in-class exercises** is to attend class. If you receive credit for 80% of the in-class exercises, you will be given 100% of the points. Note that **filling out an in-class exercise for another student is considered cheating – you will receive a zero for the in-class exercises part of the course the course and be reported to the Dean of Students and to the Associate Head of ECE.**

Class schedule

Specific reading assignments are posted on the course web site.

We will stay on schedule.

Ethics

Every member of the Purdue community is expected to practice honorable and ethical behavior both inside and outside the classroom. Any actions that might unfairly improve a student's score on homework, quizzes, or examinations will be considered cheating and will not be tolerated.

All occurrences of academic dishonesty will be reported to the Assistant Dean of Students and copied to the ECE Associate Head of Education. If there is any question as to whether a given action might be considered as cheating, please see the instructor or the teaching assistant before you engage in any such action.

Ethics

Examples of cheating include (but are not limited to):

- Sharing results or other information during an examination.
- Bringing forbidden material or devices to an examination.
- Working on an exam before or after the official time allowed.
- Requesting a re-grade of answers or work that has been altered.
- Submitting homework or a SPICE project that is not your own work.
- **Submitting an in-class quiz for another student.**

Emergencies

In the event of a campus emergency, course requirements, deadlines and grading percentages are subject to changes.

Ways to get information about changes in this course.

- Course webpage on Purdue Blackboard
- Instructor's email
- Instructor's phone

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.

See the syllabus and the University's website for additional information: https://www.purdue.edu/ehps/emergency_preparedness/

How to succeed in ECE 255

- Do the assigned reading **before class**
- Attend class and pay attention
- **Review the lecture after class**
- Do the HW **without** looking at the solutions
- Review and understand the solutions
- Be sure you understand the in-class exercises
- Don’t memorize complicated formulas
- **Ask questions**

Advice from working engineers

1) Developing a deep understand the fundamentals should be your top priority.

2) Familiarity with rapidly changing current and emerging technologies is also needed.

3) Technical knowledge must be complemented by soft-skills such as an ability to communicate, a talent for working in multi-disciplinary teams, project management, etc.

4) Technology stars have a set of personal characteristics beginning with ethics and integrity. They are results-focused. They always strive to over-deliver. They're passionate for the work. They drive change rather than just try to keep up.

Course website

Grades will be posted on Blackboard

All other materials (syllabus, reading assignments, HW assignments and solutions, practice exams, PowerPoint lectures, etc.) are available at

https://nanohub.org/groups/ece255_2019

for Wednesday, 1/9

1) Review KCL, KVL, Thévenin and Norton equivalents

2) Read Sec. 1.1-1.6 and 3.1

4) Begin HW 1 (**due Mon. Jan. 14 5:00 PM in MSEE 180**)

Questions?

Good luck in ECE-255!

Get started right away!