Lecture 1
Course Overview and Why You Should Care

Prof. Aaron Franklin

ECE 230L, Duke University

Introduction to Microelectronic Devices and Circuits

FALL 2017

Outline

- Overview of course policies
- Piazza
- Socrative
- History of the transistor
- Moore's Law
- Computing from MOSFETs
- Why circuits matter

Syllabus

- Office hours
- Textbook
  - E-Book – Introduction to Microelectronic Devices and Circuits. ISBN – 9781121962194.
    - Students can purchase the e-book directly from McGraw-Hill using a credit card by logging into https://create.mheducation.com/shop/ and searching by ISBN (note that the instructor name listed may not be accurate, but if the School is "Duke University" and the title is correct, then it is the right book).
- Grading criteria
  - Homework 20%
  - Quizzes 10%
  - Laboratory 10%
  - Midterms (2) 15% each
  - Final Exam 20%

Laboratory

- Lab section of course runs as a completely separate operation under direction of Kip Coonley
  - **Begins:** THIS WEEK!
  - **Location:** Hudson Hall 02H (basement)
  - **No lab notebook required**
  - **You MUST attend your specific lab section you are registered for**
- The lab is a key component of this course and will correlate with the material covered in lecture
- Questions about the lab should be directed to the lab TAs or tagged with the "lab" category in Piazza

Attendance, Homework and Quizzes

- **Attendance**
  - Attending every lecture is crucial to your grade in this course
- **Homework**
  - Exam questions will be very similar to the HW questions, so understanding the HW is critical
  - HW will be due at the very beginning of lecture on the indicated due date. **NO LATE HW WILL BE ACCEPTED (see syllabus)**
- **Quizzes**
  - Held ~once per week at the very beginning of lecture (see schedule)
  - Will focus primarily on material from that day's scheduled reading assignment (see schedule)

TAs

- Lab TAs
  - Run the lab and are available for assistance with lab-related work
- Course TAs
  - Hold office hours for homework & course content help
  - Grade homework (discuss grading errors directly with them)

GTAs: Steven Noyce (steven.noyce@duke.edu) (Lecture, office hour: Fri. 10–11am, CIEMAS 3rd floor)
Jimmy Thostenson (james.thostenson@duke.edu) (Lecture, office hour: Tues. 9–10am, CIEMAS 3rd floor)
UGTAs: Sujay Garlanka (sujay.garlanka@duke.edu) (Lecture, office hour: Mon. 5–6pm, CIEMAS 3rd floor)
Gerry Chen (gdc9@duke.edu) (Lab 01L Tu 3:05–6:05PM)
Yao Yuan (yy123@duke.edu) (Lab 02L W 3:05–6:05PM)
Martin Li (ml328@duke.edu) (Lab 03L Th 3:05–6:05PM)
Michael Kuryshev (michael.kuryshev@duke.edu) (Lab 04L F 10:05AM–1:05PM)

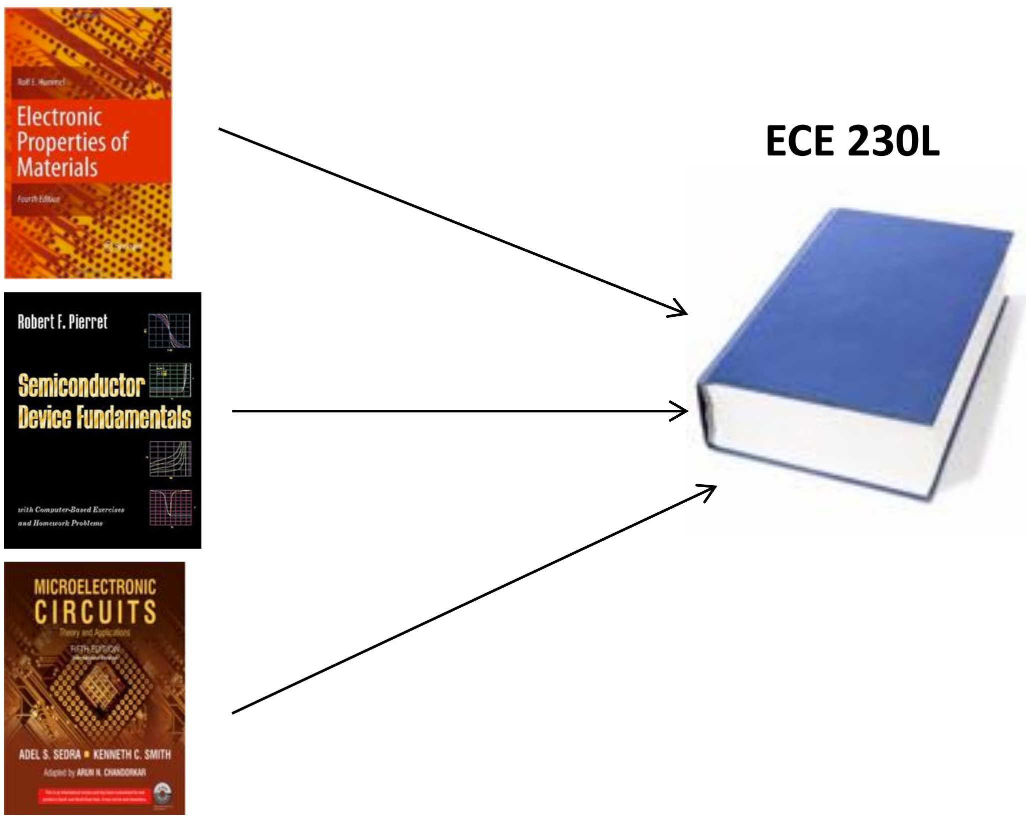
Schedule

Date	Lab		Lecture	Reading	HW/Quiz
T, 8/29	SMIF Intro	Semiconductor Materials	Course overview The Big Picture: Why Care About This Course?		
Th, 8/31			Crystal Structure of Solids	pg. 9-32	
T, 9/5	SMIF Tour		Quantum Theory of Solids (band structure)	pg. 34-48	Quiz #1
Th, 9/7			Quantum Theory of Solids (electrical transport)	pg. 48-81	HW #1 due
T, 9/12	Photolith I		Thermal Equilibrium	pg. 82-131	Quiz #2
Th, 9/14			Carrier Transport (drift)	pg. 132-147	HW #2 due
T, 9/19	Photolith II		Carrier Transport (diffusion)	pg. 148-155	Quiz #3
Th, 9/21		Devices	pn Junction Diodes (junction under zero-bias and reverse-bias)	pg. 169-190	HW #3 due
T, 9/26	pn Junction Diodes		pn Junction Diodes (junction under forward bias, ideal diode, deviations from ideal, light emitting diode)	pg. 204-232, 290-296	Quiz #4
Th, 9/28			**EXAM 1 – *Semiconductor Materials***		
T, 10/3	P-Spice Circuit Simulatn		pn Junction Diodes (small-signal equivalent circuit, diode transients)	pg. 232-245, 425-430	HW #4 due
Th, 10/5			pn Junction Diodes (large-signal analysis, half-wave rectifier)	pg. 416-425, 449-453	Quiz #5
T, 10/10	**NO LAB**		**FALL BREAK**		
Th, 10/12			MOSFETs (MOS capacitors)	pg. 313-336	HW #5 due
T, 10/17	Project Intro		MOSFETs (capacitance-voltage characteristics)	pg. 336-345	Quiz #6
Th, 10/19			MOSFETs (basic MOSFET operation)	pg. 345-364	HW #6 due
T, 10/24	MOSFET		MOSFETs (small-signal equivalent circuit, CMOS technology, circuit symbols)	pg. 364-373, 519-523	Quiz #7
Th, 10/26		Circuits	Digital (NMOS inverters)	pg. 547-550, 836-850	HW #7 due
T, 10/31	MOSFET Model		Digital (CMOS inverters and logic gates)	pg. 861-885	Quiz #8
Th, 11/2			**EXAM 2 – *Devices***		
T, 11/7	Basic Digital Circuits		Analog (DC Biasing of MOSFET circuits)	pg. 528-543	HW #8 due
Th, 11/9			Analog (common-source MOSFET amplifier)	pg. 550-551, 587-608	
T, 11/14	Multistage Amplifiers		Analog (common-drain, common-gate MOSFET amplifiers)	pg. 609-620	Quiz #9
Th, 11/16			Analog (single-stage MOSFET IC, multistage amplifiers)	pg. 620-626, 629-640	HW #9 due
T, 11/21	**NO LAB**		Analog (operational amplifier)	pg. 672-692	Quiz #10
Th, 11/23			**THANKSGIVING BREAK**		
T, 11/28	Op-Amp		Analog (operational amplifier applications)	pg. 692-708	HW #10 due
Th, 11/30			The Big Picture: Why does this matter? Future directions		Quiz #11
T, 12/5	Project Demos		"Create Final Exam" project		HW #11 due
Th, 12/7			Course Review for Final Exam		
Sa, 12/16			**FINAL EXAM, 2pm – 5pm – *Comprehensive***		

Perspective on how much we have to cover

- We have a TON of material to get through!

Typical full courses



- Studying the textbook in addition to lecture will be essential!

Piazza

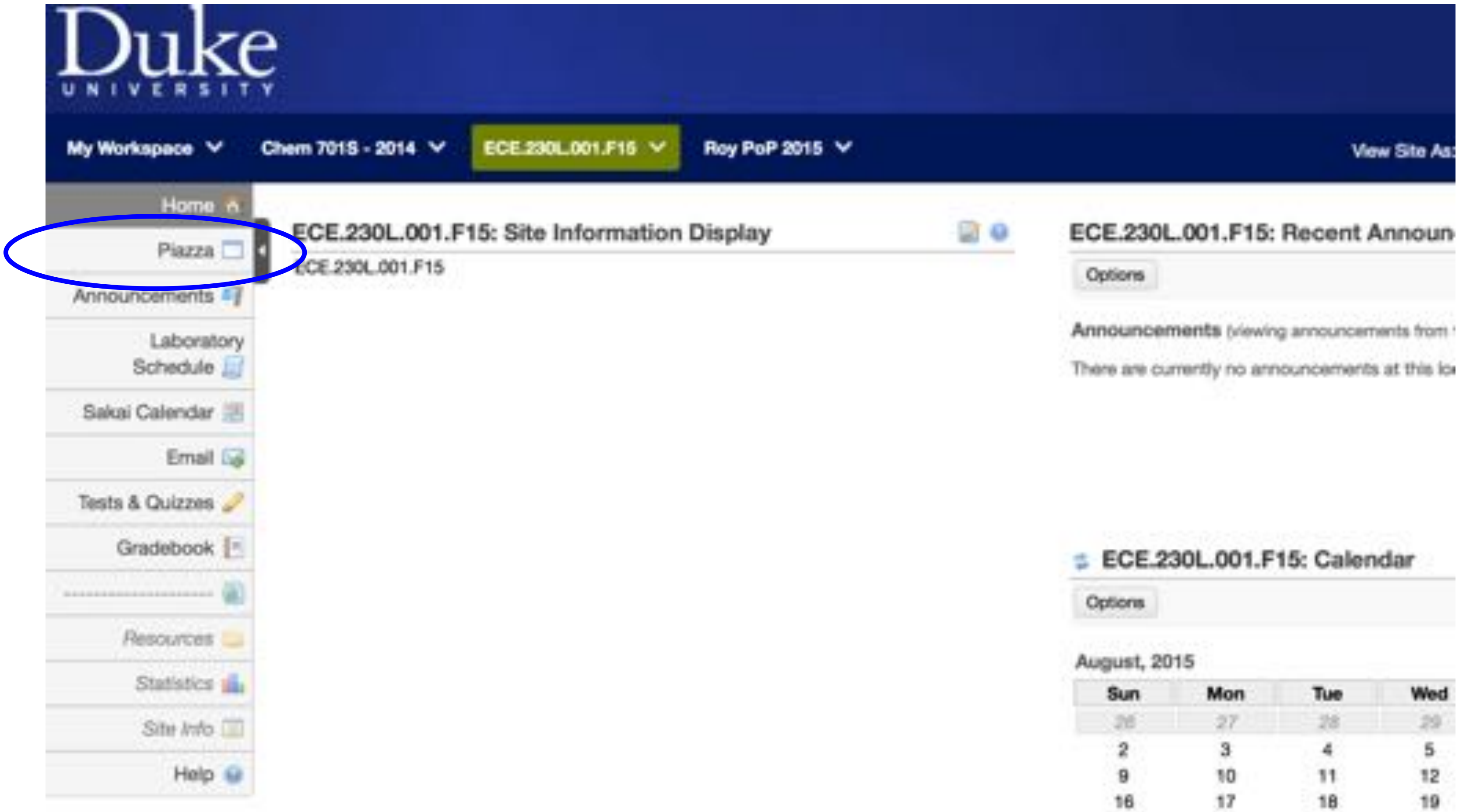
- All homework and lab questions should be posted on Piazza rather than emailed to professor/TAs
  - Only exception is for personal communications
  - **These posts can be made anonymous to the rest of the class!**

- Students are welcome to 'discuss' posted questions via Piazza, but **do not** simply give the answer to a HW problem!

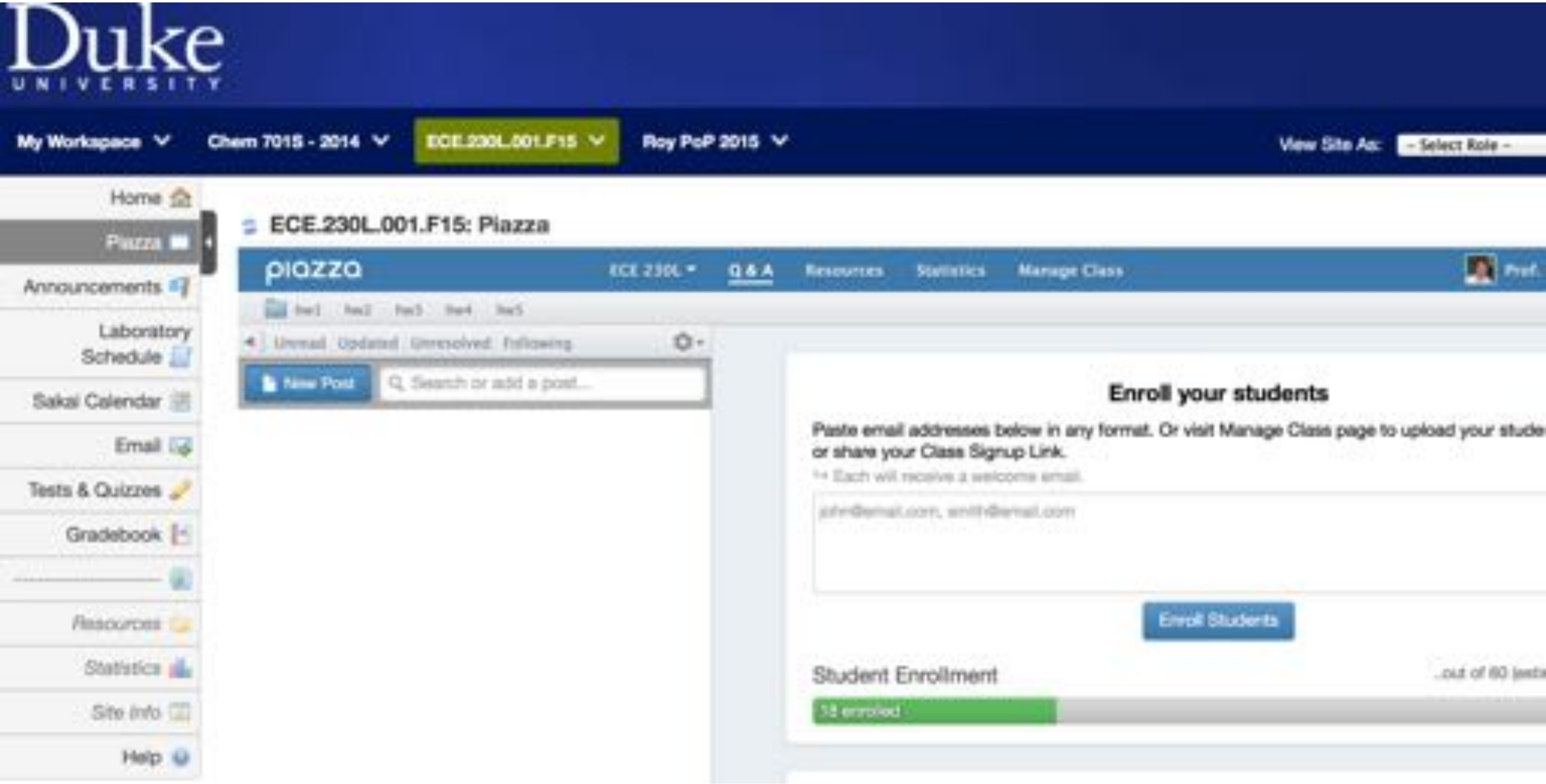
- <u>All course files will be posted under the "Resources" tab on the Piazza site</u>

Accessing Piazza

- OPTION 1: Go straight to www.piazza.com
- OPTION 2: Use tab in Sakai:

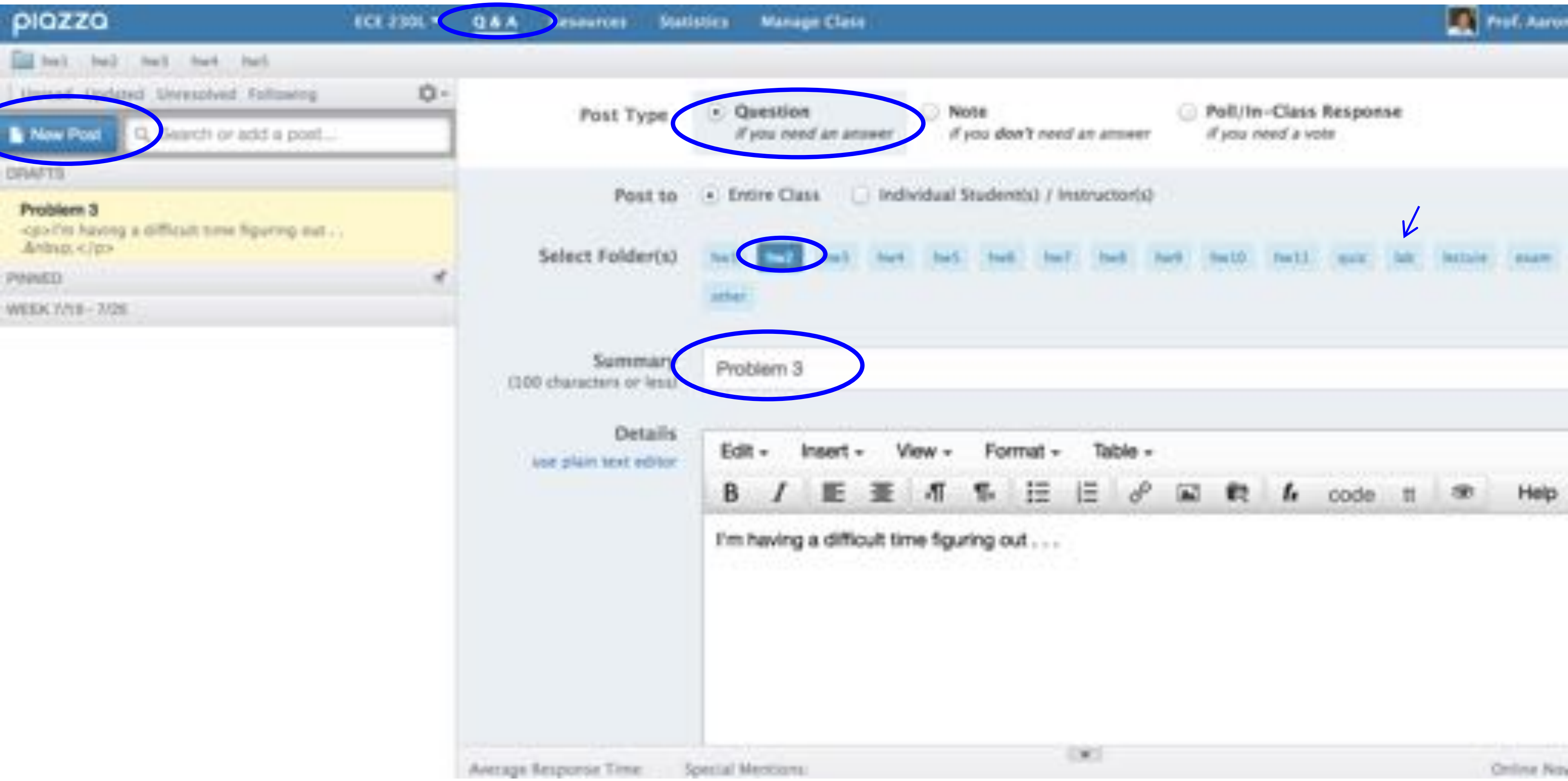


Accessing Piazza



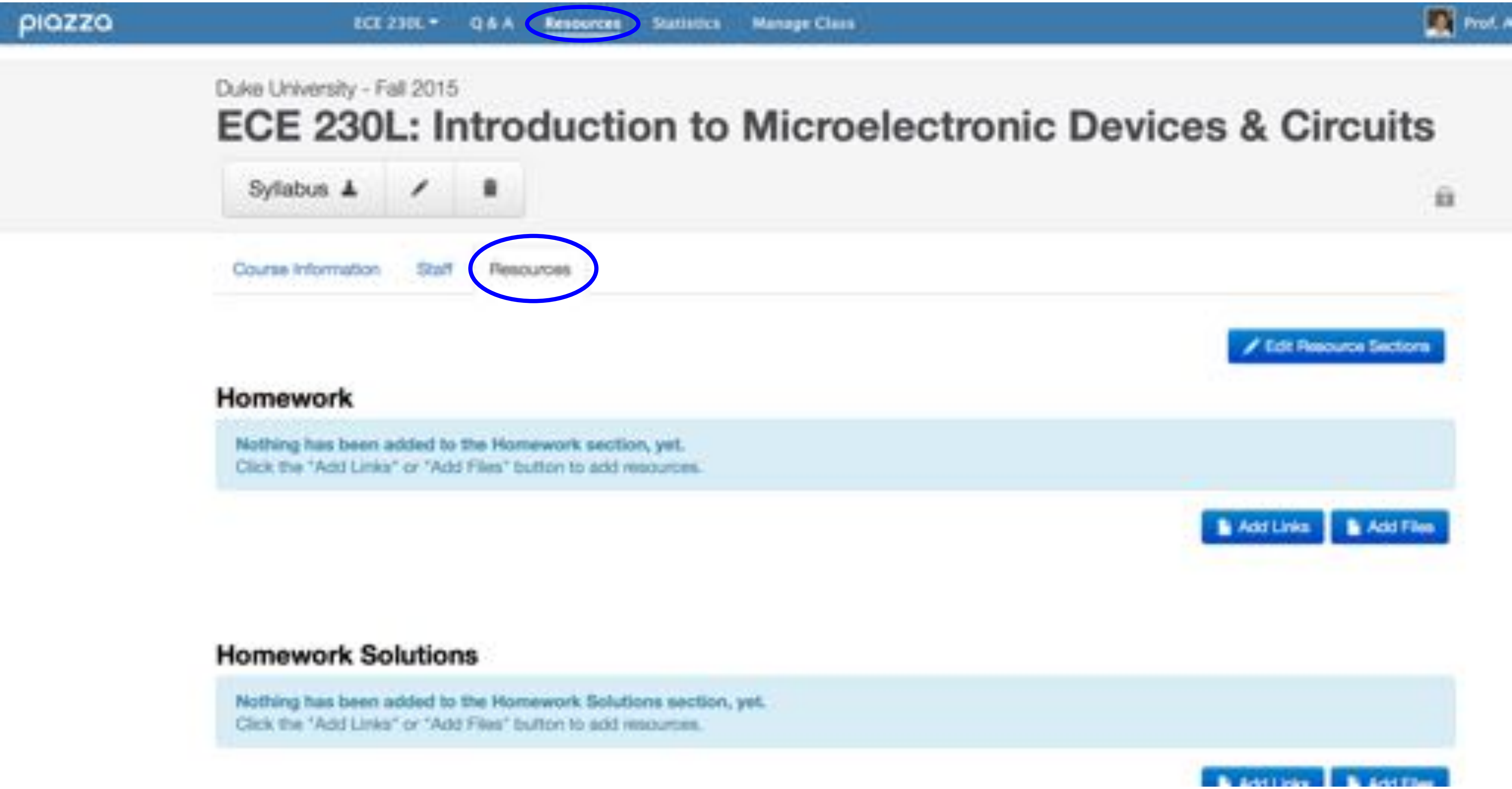
Quick Piazza Overview

- Posting a question:



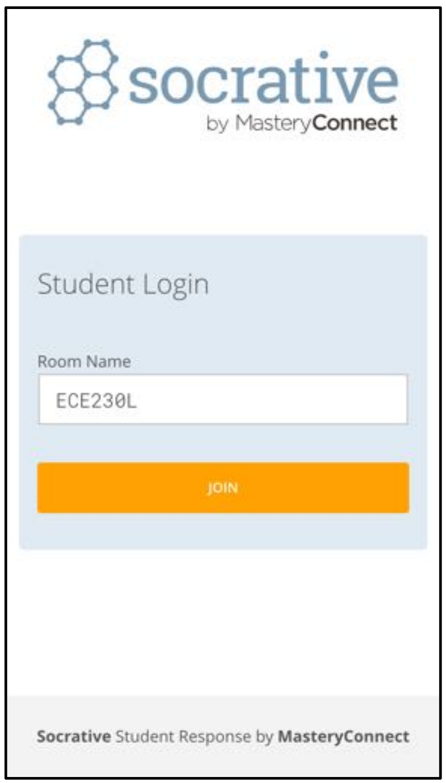
Quick Piazza Overview

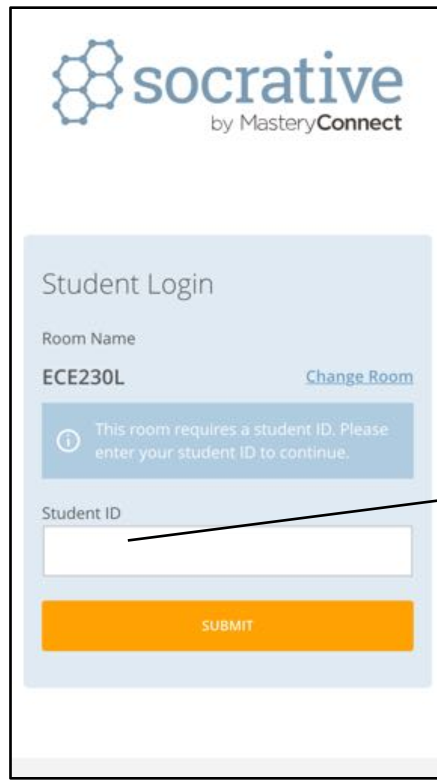
- Accessing files:



Socrative for quizzes

- We will use Socrative (www.socrative.com) **<u>for all quizzes</u>** and occasionally for in-class exercises.
- Socrative can be readily accessed with any internet-connected device (smartphone, laptop, etc.):





Duke Unique ID

Socrative for quizzes

- Socrative test
- If you have any issues with accessing Socrative, please let me know!

My background . . . through logos and mascots

B.S.E. EE

www.asu.edu

Ph.D. EE

PURDUE BOILERMAKERS

http://web.ics.purdue.edu/

Associate Professor

http://www.sportslogos.net/logos/

2004

2008

2001

2014

Component Design Engineer

intel

http://www.insidermonkey.com/

Research Scientist

IBM

www.ibm.com

COLUMBIA UNIVERSITY

Adjunct Professor

Course overview

- What <u>can</u> you learn?
  - Why a semiconductor is a semiconductor based on the arrangement of its atoms.
  - How the conducting behavior of semiconductors can be modified by “doping.”
  - What happens when you connect two disparately doped semiconductor regions to form a p-n junction.
  - How charge carriers move through semiconductor material and junctions.
  - How junctions are put together to create transistors/MOSFETs.
  - How MOSFETs are connected to yield digital circuits.
  - How MOSFETs are used to yield basic analog circuits.
  - What basic applications there are for analog circuits.
  - How an operational amplifier works and can be used.

What enables electronics?

- Looking back …

Advertisement from 1961 (General Electric)

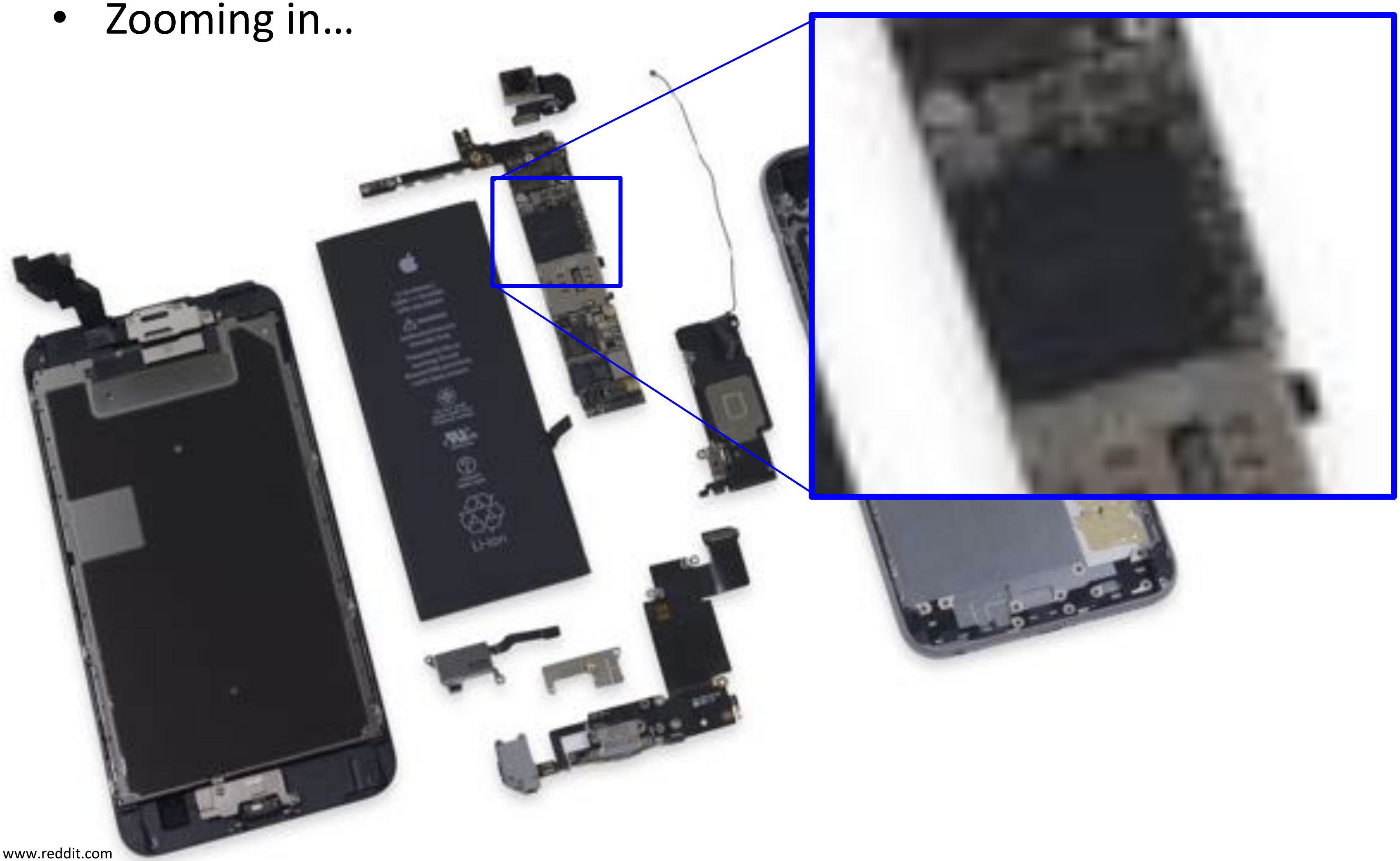
What enables electronics?

- Zooming in…

www.usatoday.com

What enables electronics?

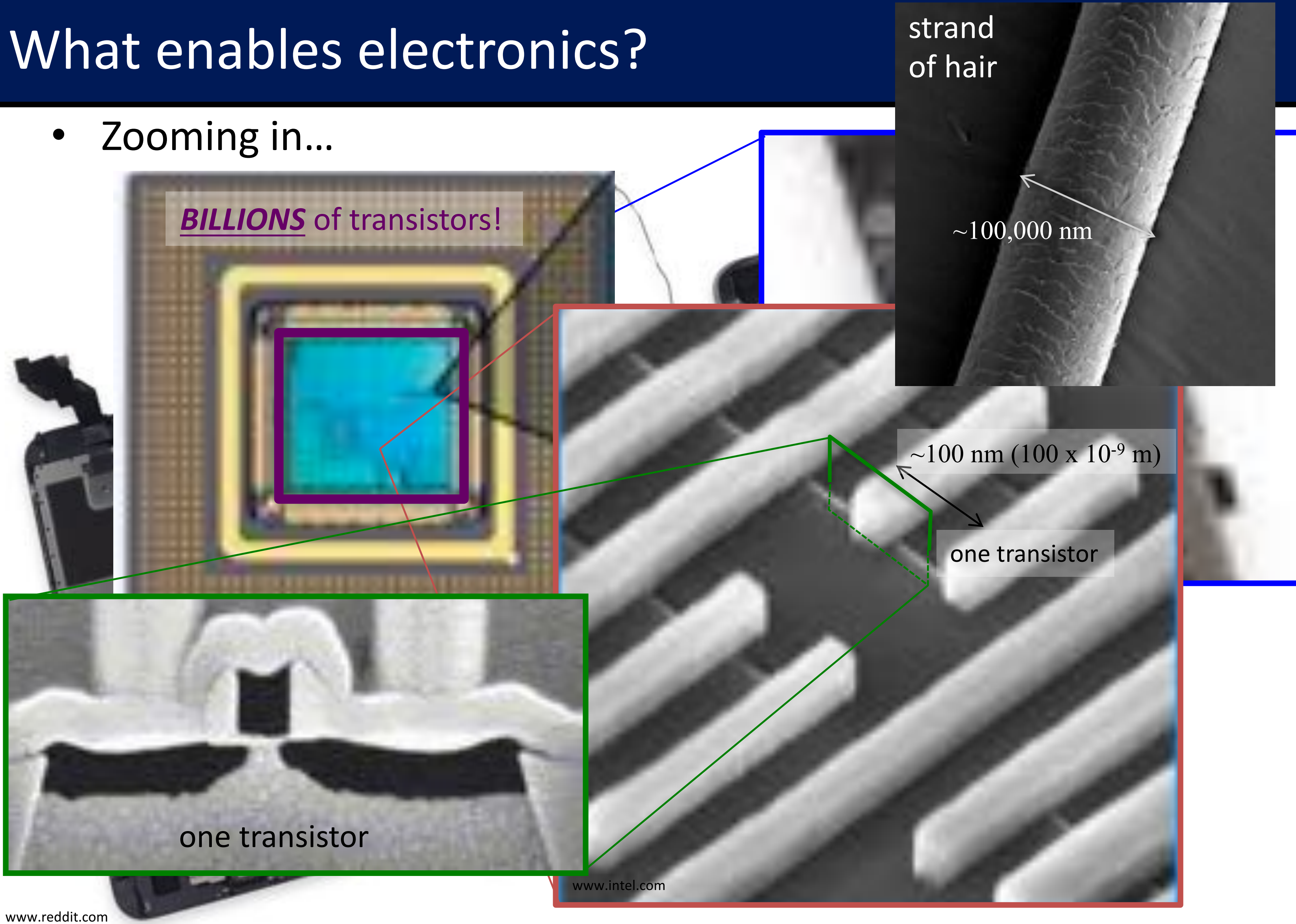
- Zooming in…



www.reddit.com

What enables electronics?

- Zooming in…



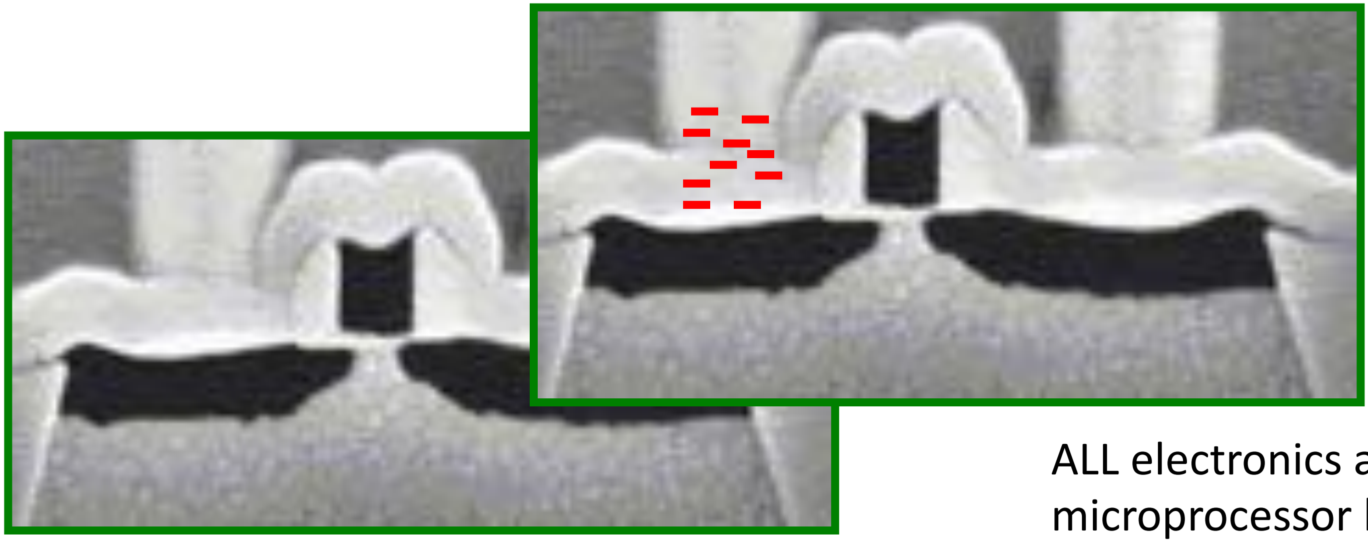
What enables electronics?

- Zooming in…

It’s a switch . . .
OFF: electric current doesn’t flow
ON: current flows

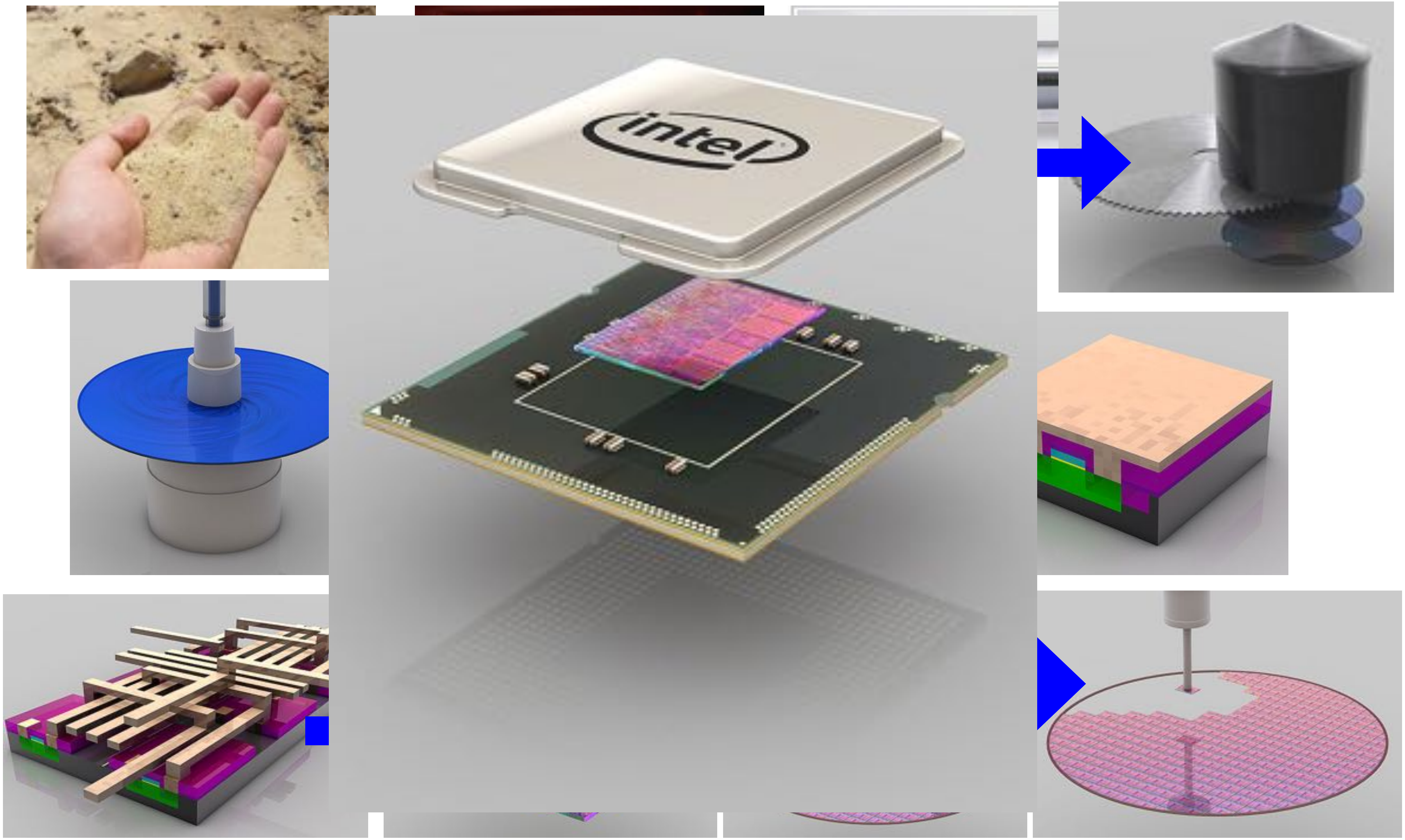
Properly combining these 0’s (off) and 1’s (on) switches together yields computation (*not just a math thing!*).

The more transistors you can put together (properly), the more you can do (faster electronics).



ALL electronics are enabled by a microprocessor brain that is a chip of BILLIONS of transistors!

Side note: How do you make silicon transistors?



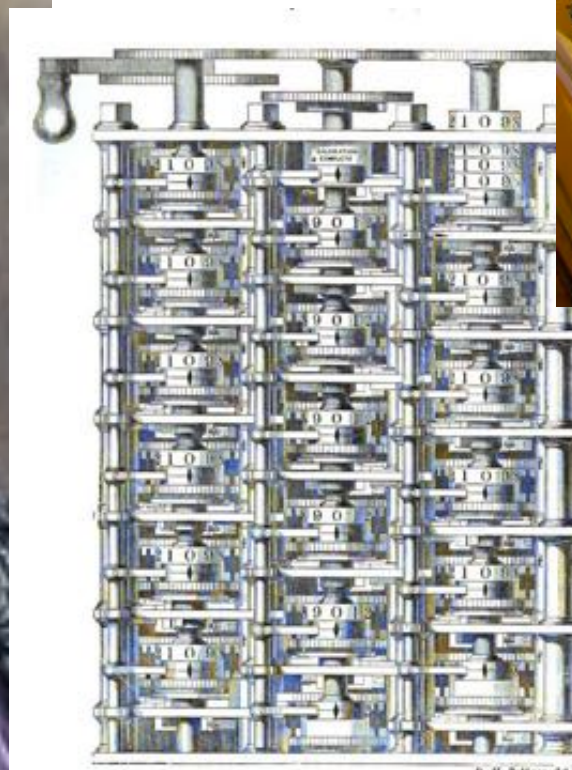
http://apcmag.com/picture-gallery-how-a-chip-is-made.htm/

What enables electronics?

- Looking back …

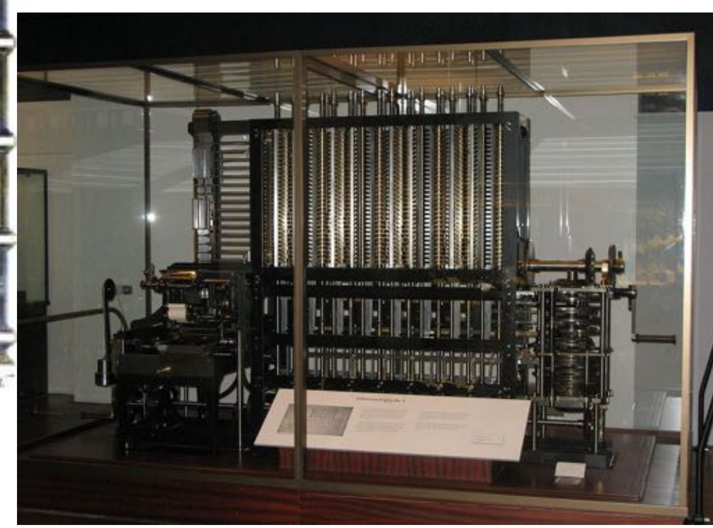
Ada Lovelace (1840's, England)

"First computer programmer"



Charles Babbage's "difference engine"—first programmable computer

Late 1800's: Mechanical computers



www.wikipedia.org

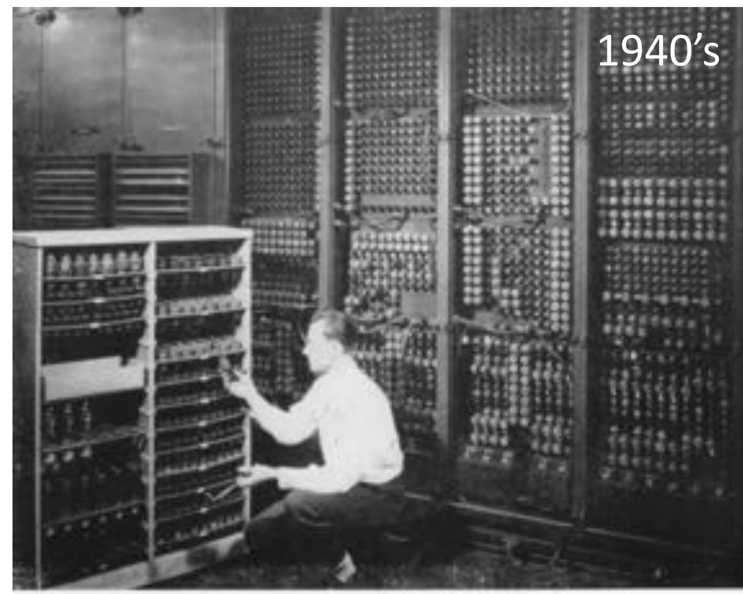
History of the transistor

- First: The vacuum tube

1918 → 1960's

→ Applying voltage to a filament and plate allows for rectification, amplification, or switching of electrical signals.

→ Crucial role in development of radio communications and early computing.

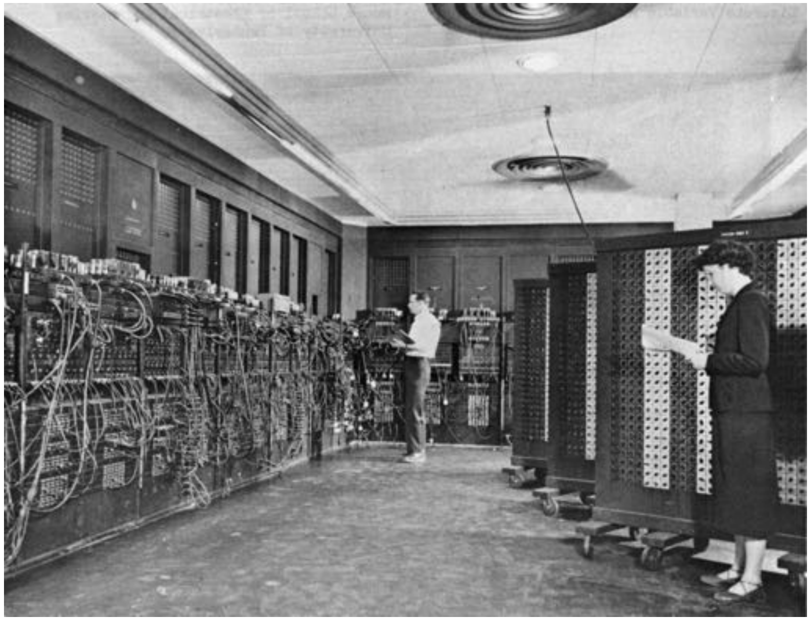


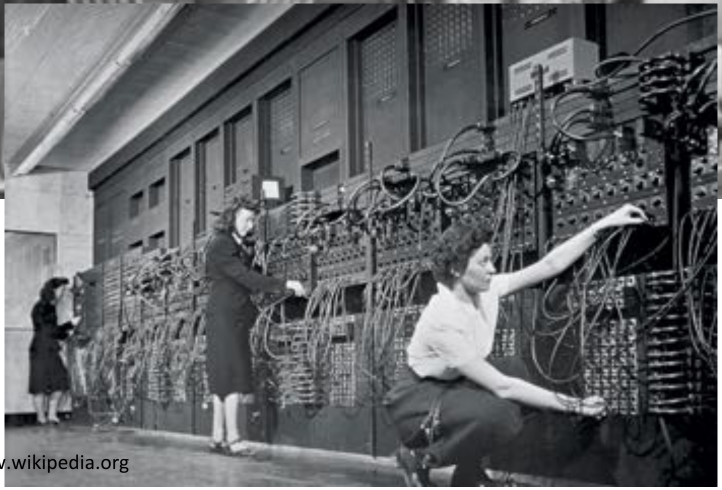
Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

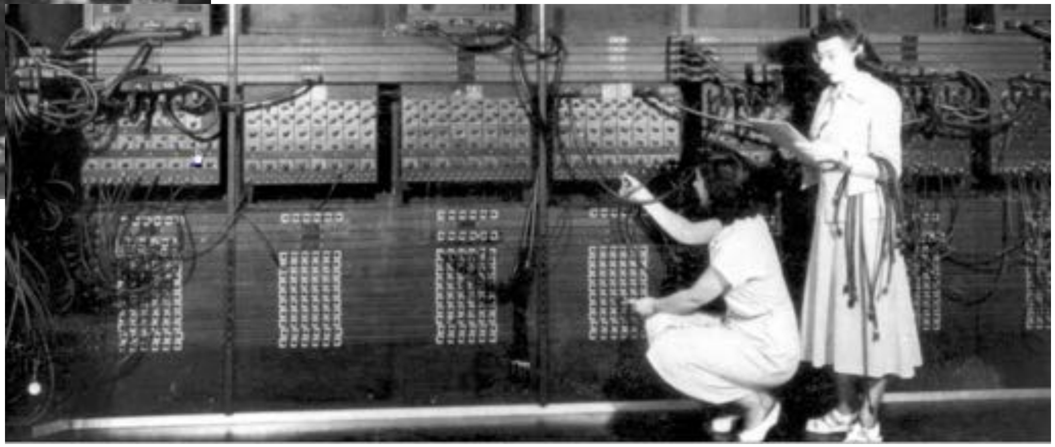
What enables electronics?

- Looking back …

once again, first programmers were women!





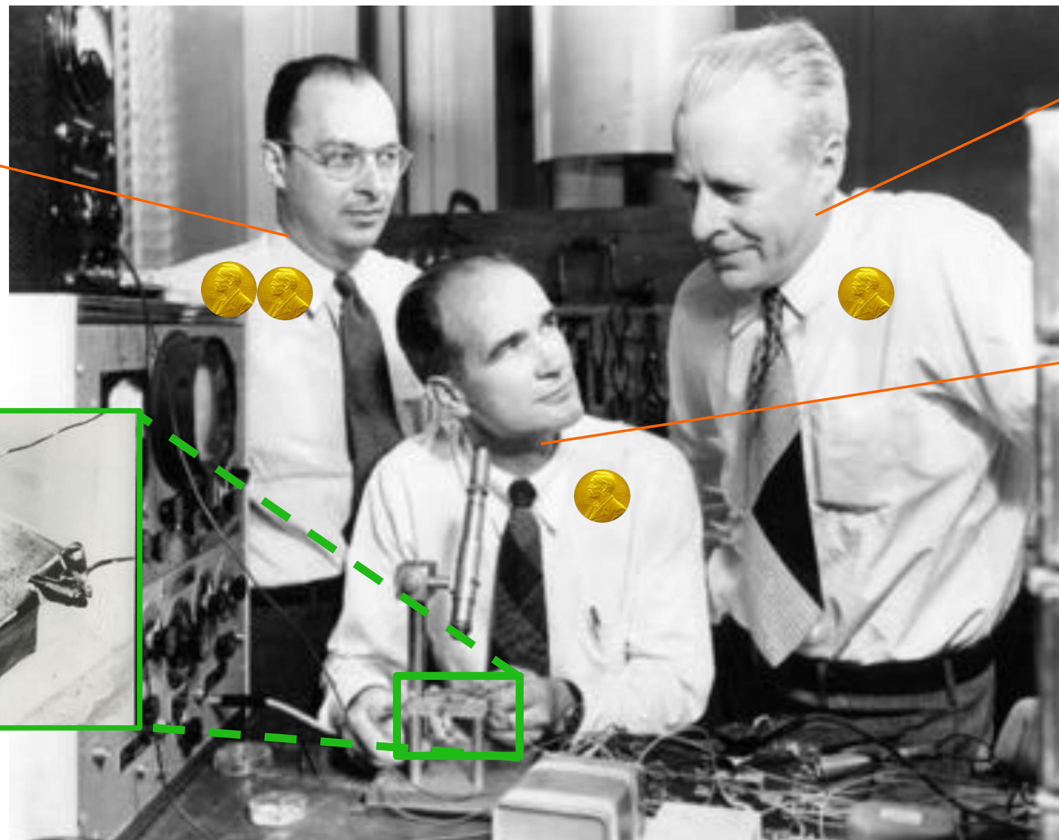


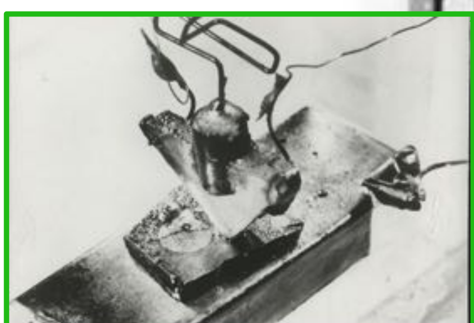
www.wikipedia.org

History of the transistor

- Bell labs pursues understanding of semiconductor physics and . . .
  - the transistor was born.

John Bardeen
theorist





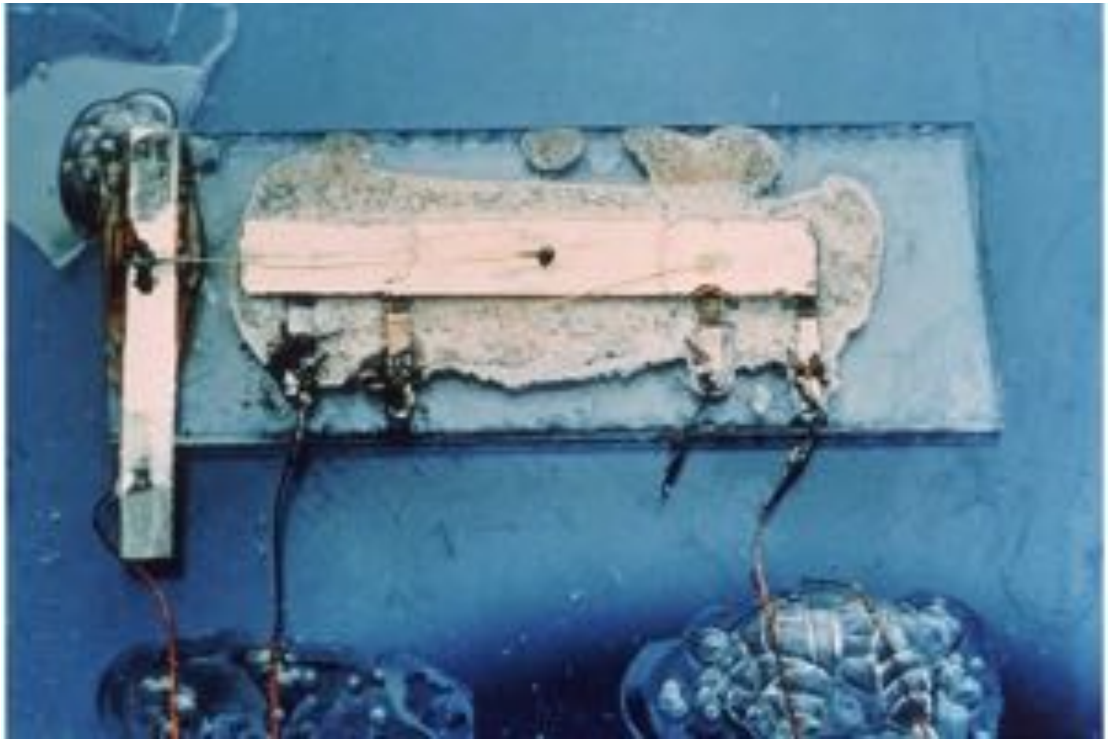
http://en.wikipedia.org/wiki/History_of_the_transistor

Walter Brattain
experimentalist

William Shockley
management / ideas

History of the transistor

Integrated circuit (IC) made the transistor *revolutionary*



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

Jack Kilby (TI) → germanium and first patent (1959)

Robert Noyce (Fairchild) → silicon and first full technology (1960's)

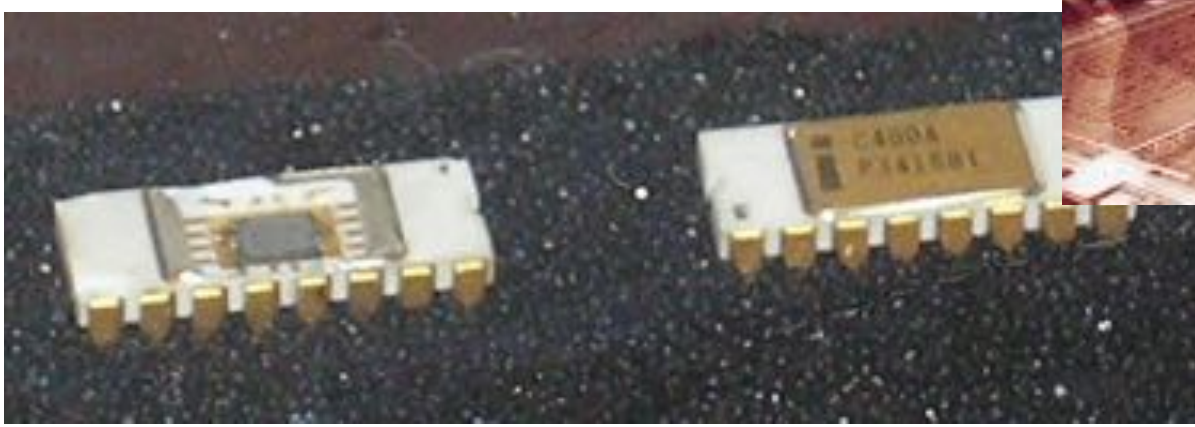
History of the transistor

- Looking back …

→ IC's used mostly by government for first few years

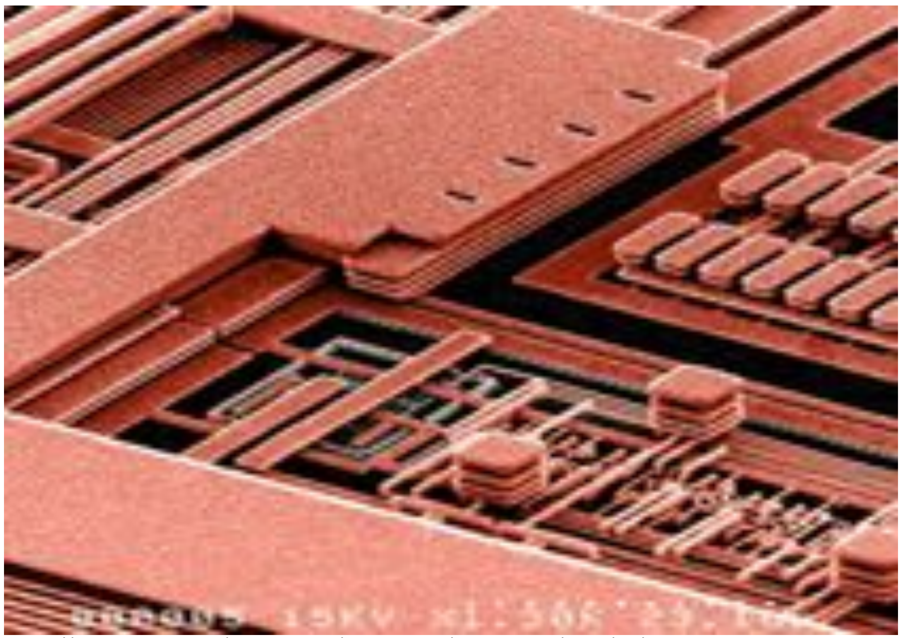
→ First consumer IC, microprocessor (Intel 4004)

  - 1971
  - 2,300 transistors

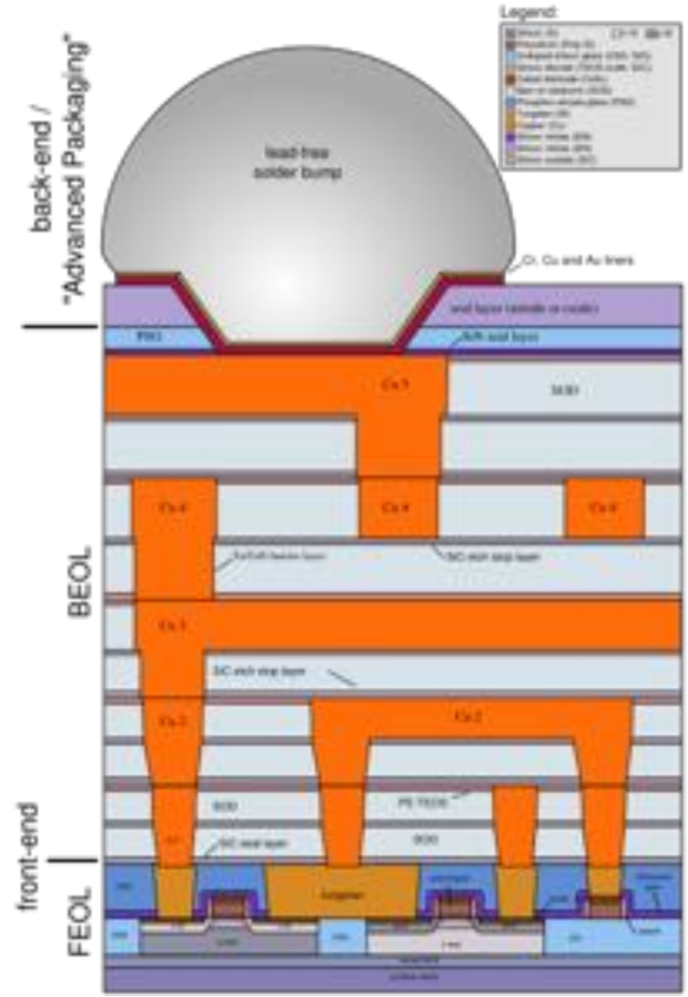


http://en.wikipedia.org/wiki/Intel_4004

- SSI → MSI → LSI → VLSI → ULSI



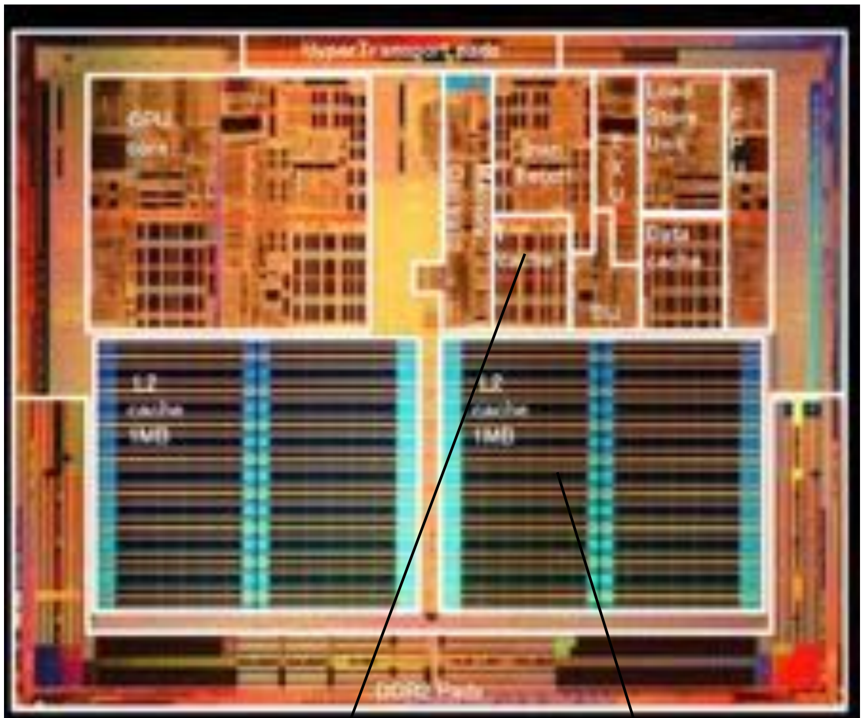
http://www.copper.org/publications/newsletters/innovations/2006/01/copper_nanotechnology.html



Importance of memory devices

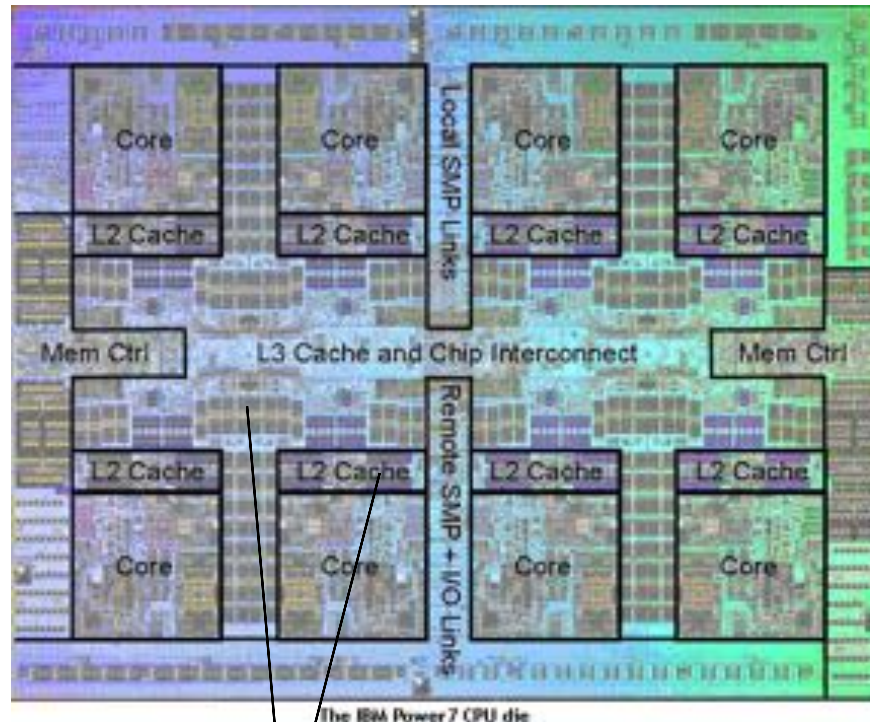
- Allocation of chip real estate—how much is memory (cache)?

AMD Dual Core



http://www.cyberindian.net/2006/06/02/amd-athlon-64-fx-62-dual-core-processor-for-amd-socket-am2-now-available/

IBM Multi Core



http://www.edn.com/electronics-news/4314117/IBM-Power7-architecture-illustrates-some-issues-for-the-rest-of-us

DRAM or SRAM

DRAM

DRAM or SRAM (but not as likely)

Moore’s Law

- Gordon Moore working at Fairchild Semiconductor made an observation in 1965:

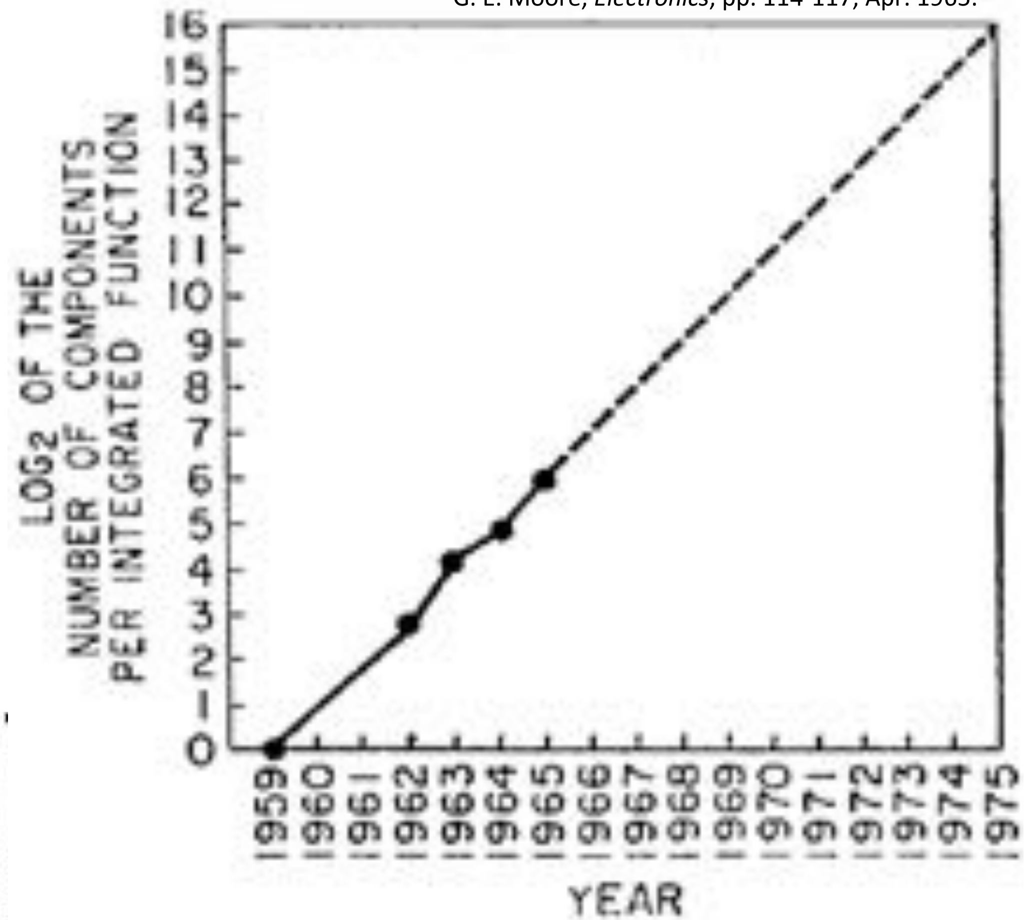
G. E. Moore is one of the new breed of electronic engineers, schooled in the physical sciences rather than in electronics. He earned a B.S. degree in chemistry from the University of California and a Ph.D. degree in physical chemistry from the California Institute of Technology. He was one of the founders of Fairchild Semiconductor and has been Director of the research and development laboratories since 1959.

VII. Heat Problem

Will it be possible to remove the heat generated by tens of thousands of components in a single silicon chip?

If we could shrink the volume of a standard high-speed digital computer to that required for the components themselves, we would expect it to glow brightly with present power dissipation. But it won’t happen with integrated circuits. Since integrated electronic structures are

G. E. Moore, *Electronics*, pp. 114-117, Apr. 1965.



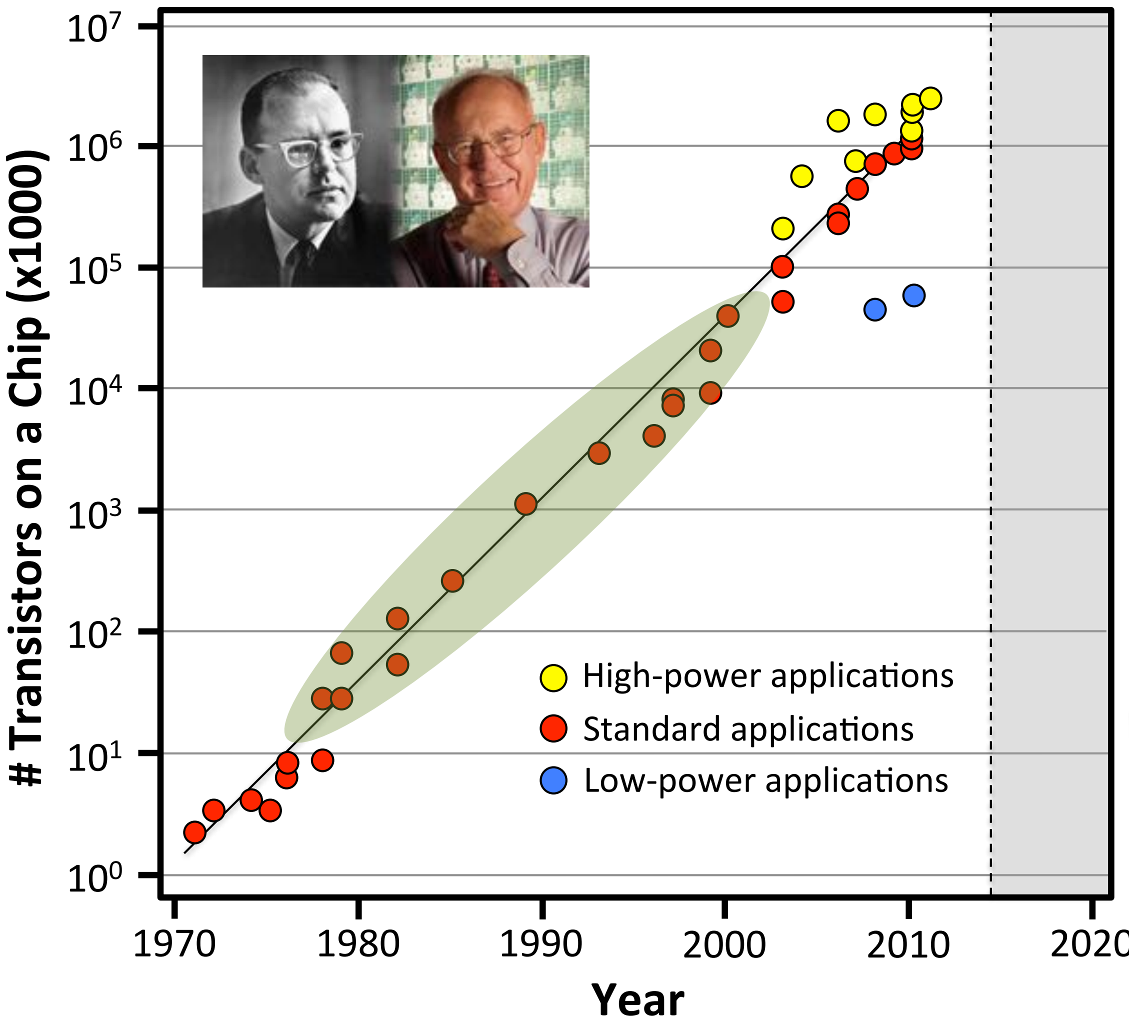
What enables electronics?

- Looking back … **<u>Moore's law</u> – 70s – 90s**

http://www.theinquirer.net/inquirer/feature/2124781/microprocessor-development

What enables electronics?

- Zooming out … **Moore's law – 70s – 90s**



IBM PC

What enables electronics?

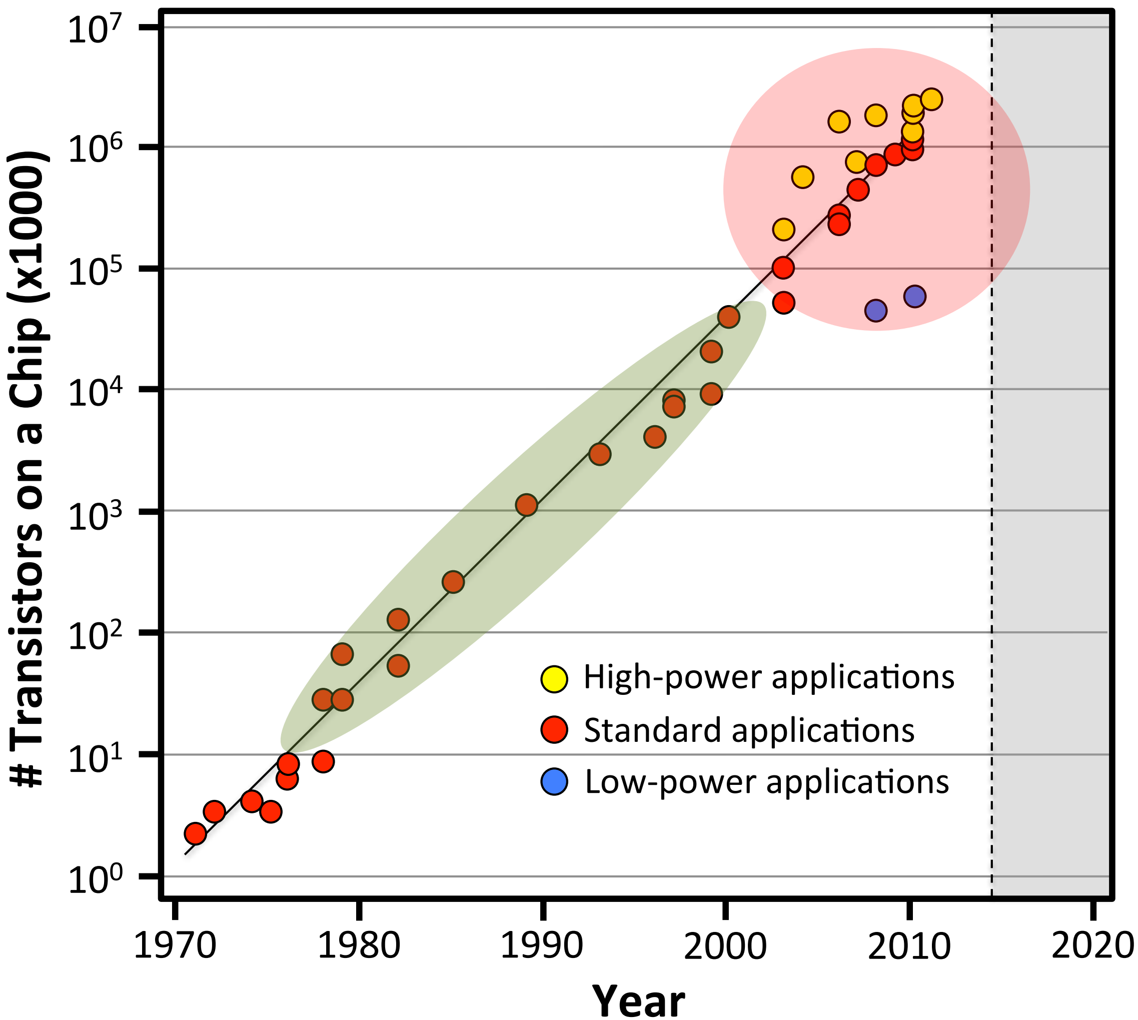
- Zooming out … **<u>Moore's law</u> – 70s – 90s**

1990's . . . Build-your-own computer era

www.wikipedia.org

What enables electronics?

- Zooming out … **Moore's law – 00s to now**



uk.businessinsider.com

Think of everything this has made possible!

- Zoming out … **Moore's law – 00s to now**

www.ultra-electronics.com