EE207 Electronic Devices and Circuits

Lecture 1: Introduction

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Why should I study this course?

Greatest Achievements of 20th century

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

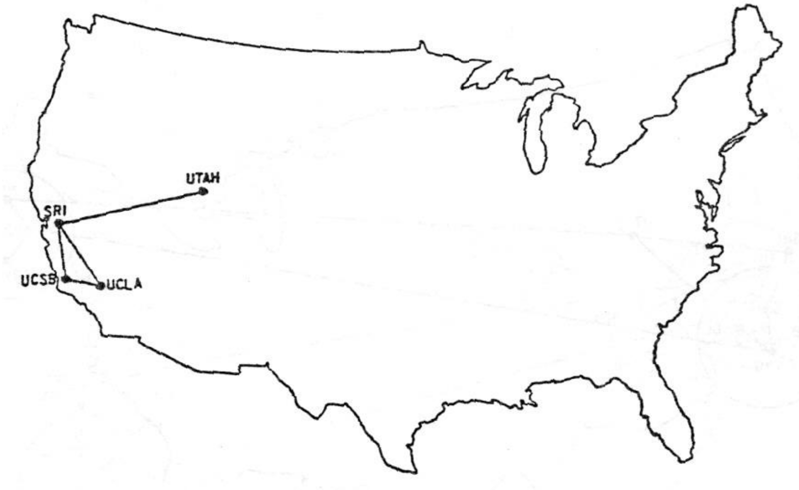
Compiled by US National Academy of Engineering

Information storage

IBM 5 MB Hard disk (1956)

Sandisk 960 GB Solid State drive (2014)

Information transfer



The ARPANET in December 1969

Information processing

Apollo guidance
computer (1969)

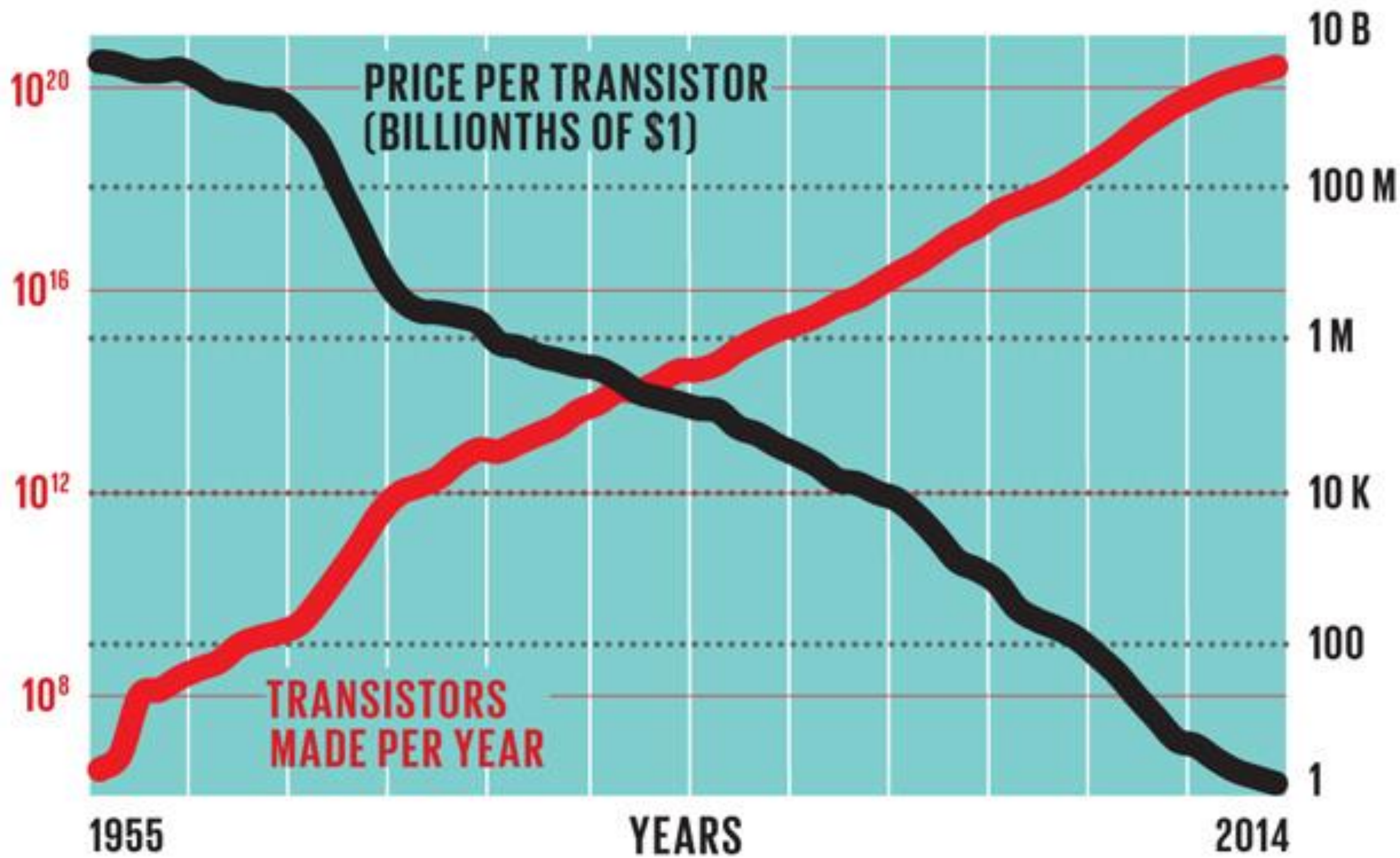
5600 logic gates

iPhone 6s (2014)

2 billion transistors

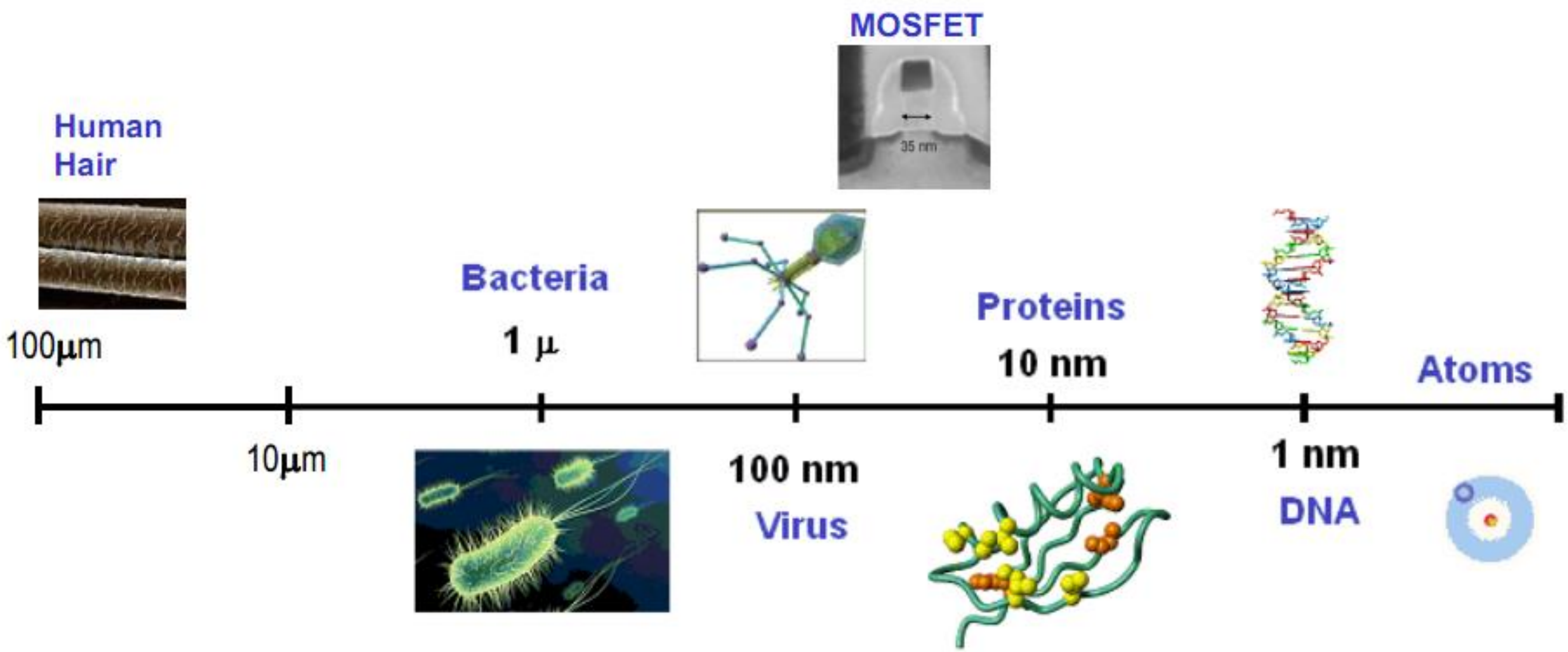
Scaling trend

IEEE Spectrum April 2015



"We are really the revolutionaries in the world today –not the kids with the long hair and beards who were wrecking the schools a few years ago" (Gordon Moore in 1973)

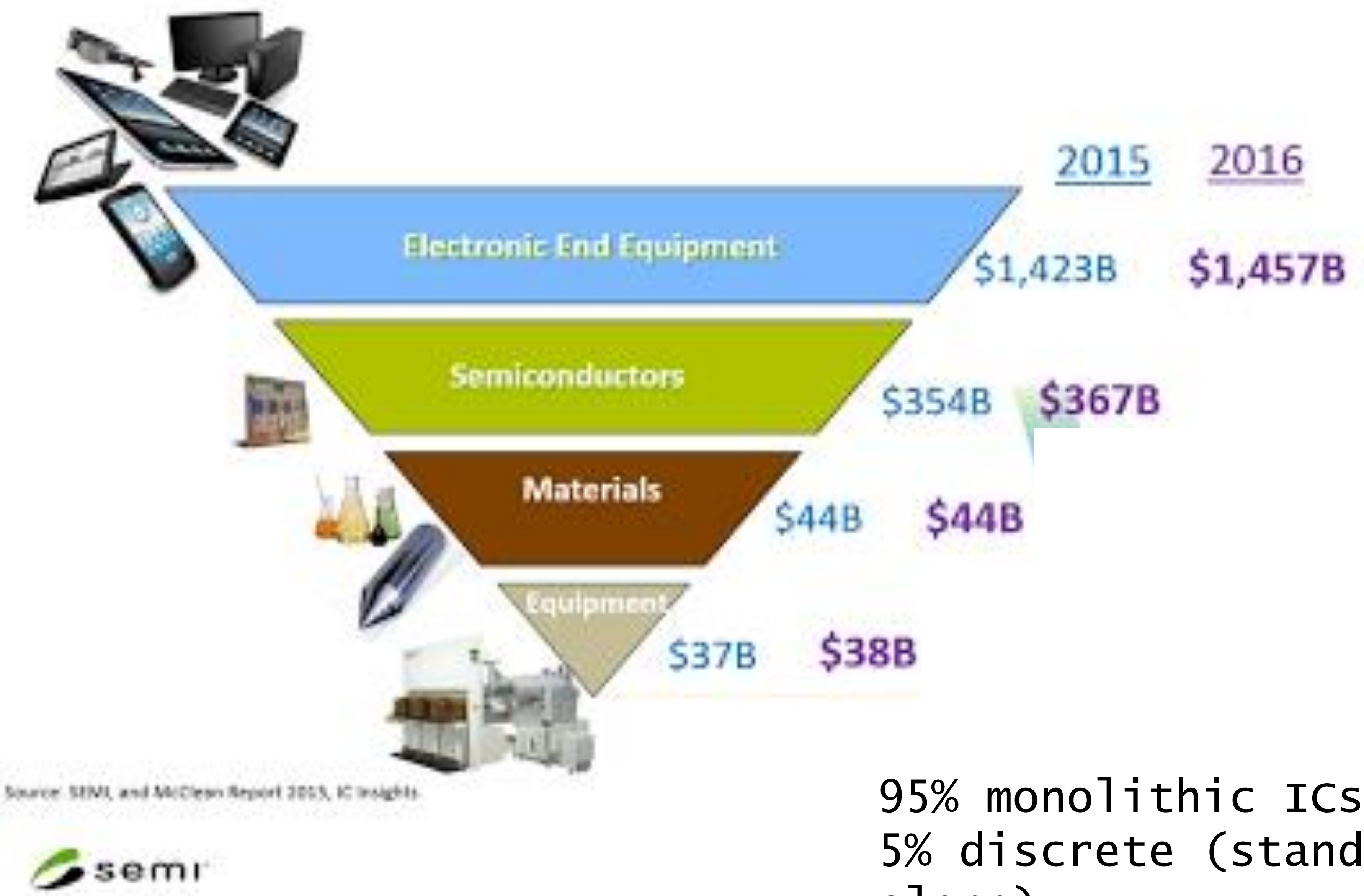
Workhorse of digital revolution



More transistors (~10^{22}/year) are produced and at a lower cost than grains of rice

Grains of rice needed to honor the promise ~ $1.8\text{x}10^{19}$

Electronic Ecosystem



95% monolithic ICs
5% discrete (stand alone)

Why should I learn about Solid State Devices ?

- Large scale integration of billions of devices not possible with other states of matter
- Foundation of digital and information revolution
- Used in all aspects of information age
  - transistors - information processing
  - LEDs, LASER, photo detector – information transfer
  - DRAM, Flash memory – information storage
- Used also in high power (power electronics) and high frequency (RF and microwave) applications
- Continuous scaling resulted in smaller, cheaper and faster devices
- Enables circuit and product designers to put more functionality for the same area and power specs

"Semiconductors are for the information society, what grain was for the agrarian society and iron and steel were for the industrial society."

Source: Adapted from the Shanghai Museum for Urban Development 2004

Course background

In the last 60 years, solid state devices served as the foundation of the digital revolution which has affected all aspects of our modern life. Although fabrication of these devices is a complex process that requires close collaboration of specialists from different disciplines, the working principles of most of these devices can be learnt at the junior undergraduate level.

Course objectives

1. Understand and explain how basic material properties affect the operation of semiconductor devices.
2. Understand how simple models can be developed and used to explain the impact of device on circuit behavior.
3. Develop the basic tools with which novel devices can be studied.

The big picture

- Why/How semiconductors are diff from metals and insulators ?
- Find carrier concentration under equilibrium
- What happens when a perturbation is made (shine light, apply voltage) ?
- Derive simple I-V relation and explain operation of basic devices
- How devices which are manufactured can be modeled accurately so that circuit designers can treat them like a black box ?
- How smaller/faster/cheaper devices can be designed ?

How SSD is different from other courses

- It is an engineering course
- Recall engineering involves art of making approximations and decisions on incomplete data
- Although this course is built on modern physics, it isn't a pure physics course
- It is also not a course which involves only pure logic and abstract maths
- It isn't a compartmentalized course where later modules can be understood without learning previous modules
- Although we give partial credit for solutions, it is very important to have a sense of numbers and its unit

EE207 ELECTRONIC DEVICES AND CIRCUITS

Modeling devices: Static characteristics of ideal two terminal and three terminal devices; Small signal models of non-linear devices. Introduction to semiconductor equations and carrier statistics: poisson's and continuity equations, Fermi-Dirac statistics and Boltzmann approximation to the Fermi-Dirac statistics. Semiconductor Diodes: Barrier formation in metal-semiconductor junctions, PN homo- and hetero- junctions; CV characteristics and dopant profiling; IV characteristics; Small signal models of diodes; Some Applications of diodes. Field Effect Devices : JFET/HFET, MIS structures and MOSFET operation; JFET characteristics and small signal models; MOS capacitor CV and concept of accumulation, depletion and inversion; MOSFET characteristics and small signal models. Bipolar transistors : IV characteristics and elers-Moll model; small signal models; Charge storage and transient response. Discrete transistor amplifiers : Common emitter and common source amplifiers; Emitter and source followers.

Text/References

•D. A. Neamen, Semiconductor Physics and Devices (IRWIN), Times Mirror High Education Group, Chicago) 1997

Pre-requisites of this course

Electrostatics

Elementary Quantum Mechanics

Text/References recommended for this course

Robert Pierret, Advanced Semiconductor Device Fundamentals
Robert Pierret, Semiconductor Device Fundamentals

Other resources

ECE 606 by Prof. M. A. Alam, Purdue University, West Lafayette, IN

available at Nanohub (www.nanohub.org)

Grading Policy

Quizzes

Midsem

Endsem

Assignments