

Lecture 1 - 6.012 Overview

September 8, 2005

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Reading assignment:

Howe and Sodini, Ch. 1

Announcement:

In Homework 1, need to use the MIT Microelectronics WebLab. Go to <http://ilab.mit.edu> to get account.

1. The microelectronics revolution

Microelectronics in the news:

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"Intel's Andrew Grove," *TIME*, December 29, 1997.

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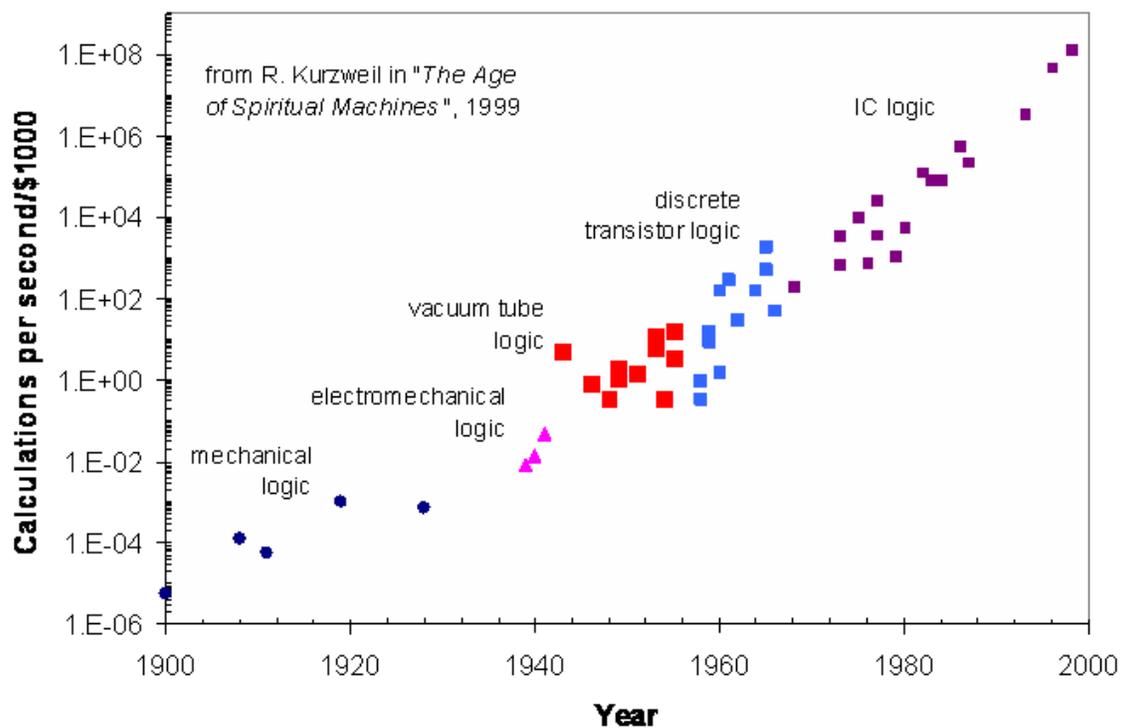
"The astonishing microchip," *The Economist*, March 23, 1996.

6.012: introductory subject to microelectronic devices and circuits

Microelectronics is cornerstone of:

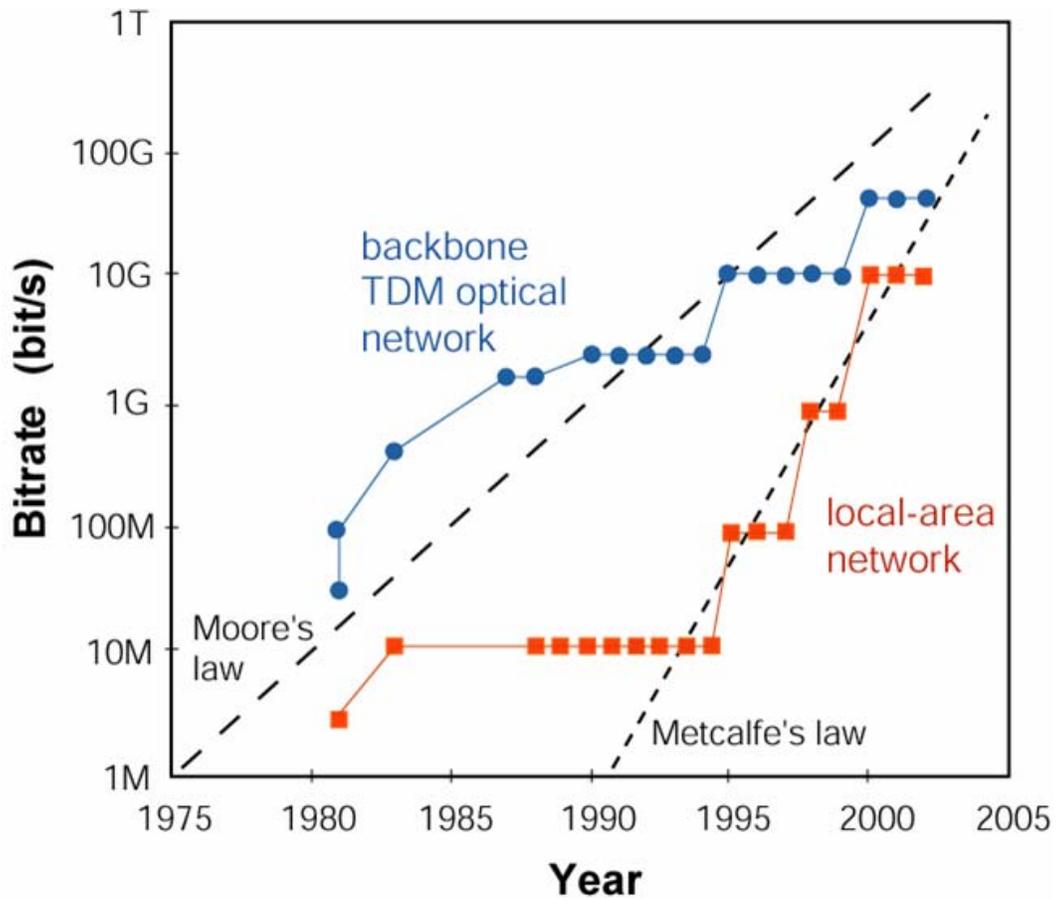
- Computing revolution
- Communications revolution
- Consumer electronics revolution

□ Microelectronics: cornerstone of computing revolution



In last 30 years, computer performance per dollar has improved more than a million fold!

□ Microelectronics: cornerstone of communications revolution



In last 20 years, communication bandwidth through a single optical fiber has increased by ten-thousand fold.

□ Si digital microelectronics today

Take the cover off a microprocessor. What do you see?

Image removed due to copyright restrictions.

[Intel Pentium IV]

- A thick web of interconnects, many levels deep
- High density of very small transistors

□ Interconnects

Image removed due to copyright restrictions.

Image of IBM copper interconnect process can be found at:

<http://www.azom.com/details.asp?ArticleID=750>

Image removed due to copyright restrictions.

Image of SEM cross-section of CMOS 7S copper process can be found at:

<http://www.azom.com/details.asp?ArticleID=750>

Today, as many as 8 levels of interconnect using Cu.

□ Transistor size scaling

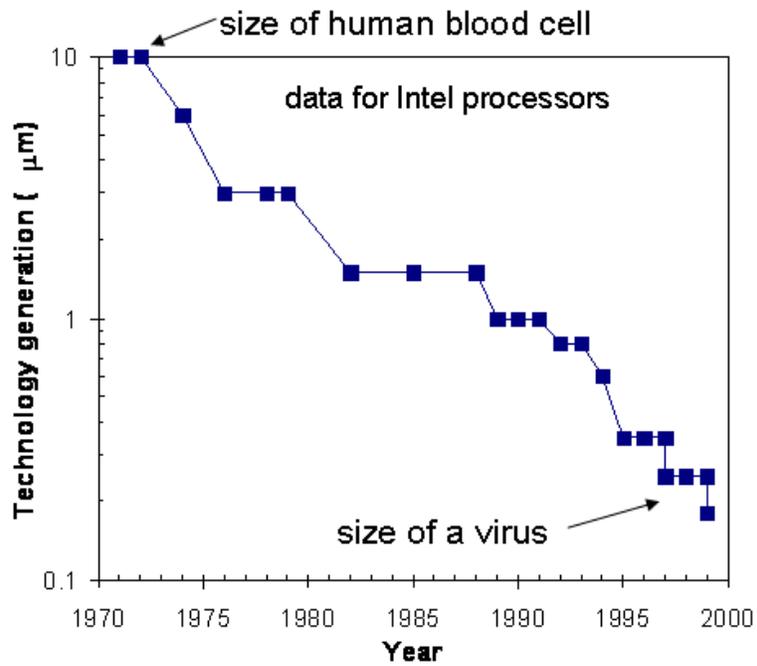
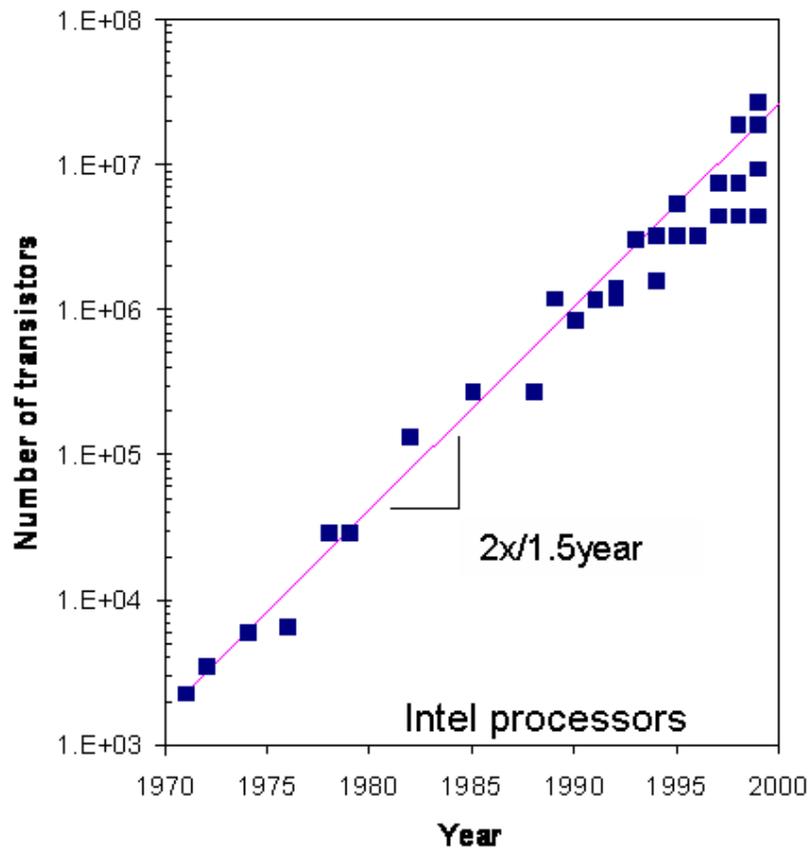


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2-orders of magnitude reduction in transistor size in 30 years.

□ Evolution of transistor density



Moore's Law:

doubling of transistor density every 1.5 years

\Rightarrow 4-orders of magnitude improvement in 30 years.

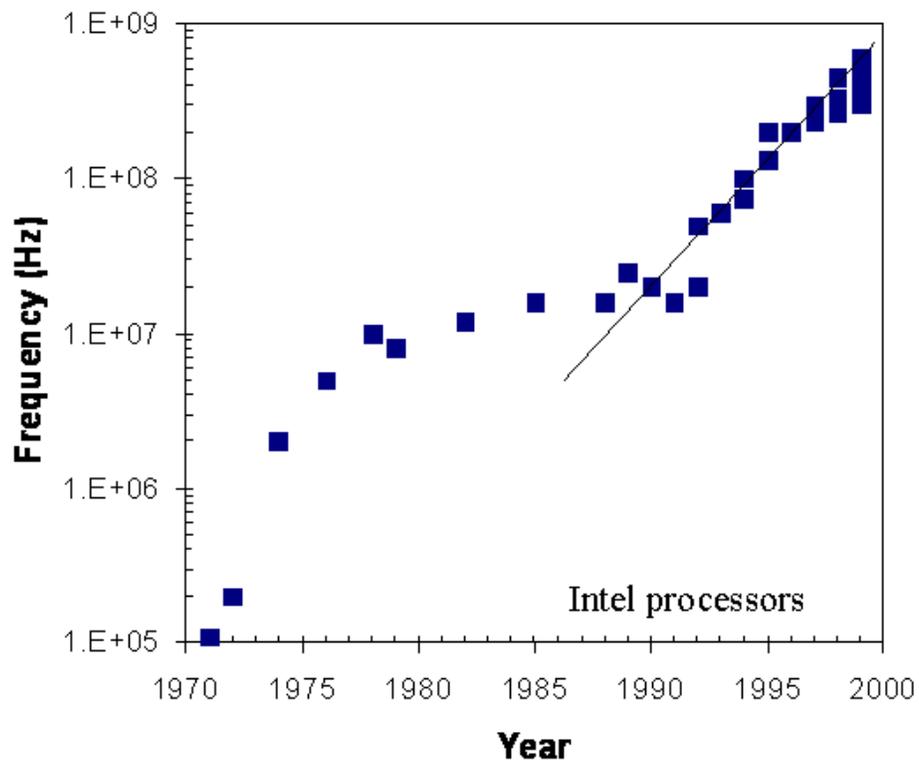
□ Benefits of continuous integration

Exponential improvements in:

- system performance
- cost-per-function
- power-per-function
- system reliability

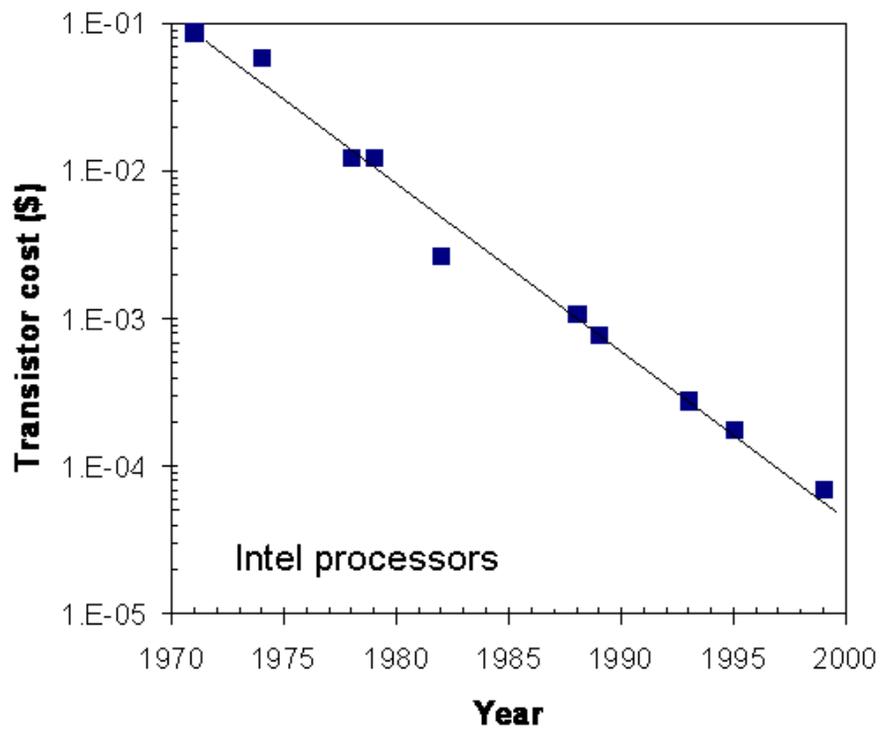
Experimental SOI IBM microprocessor. Image removed due to copyright restrictions.

□ Clock speed



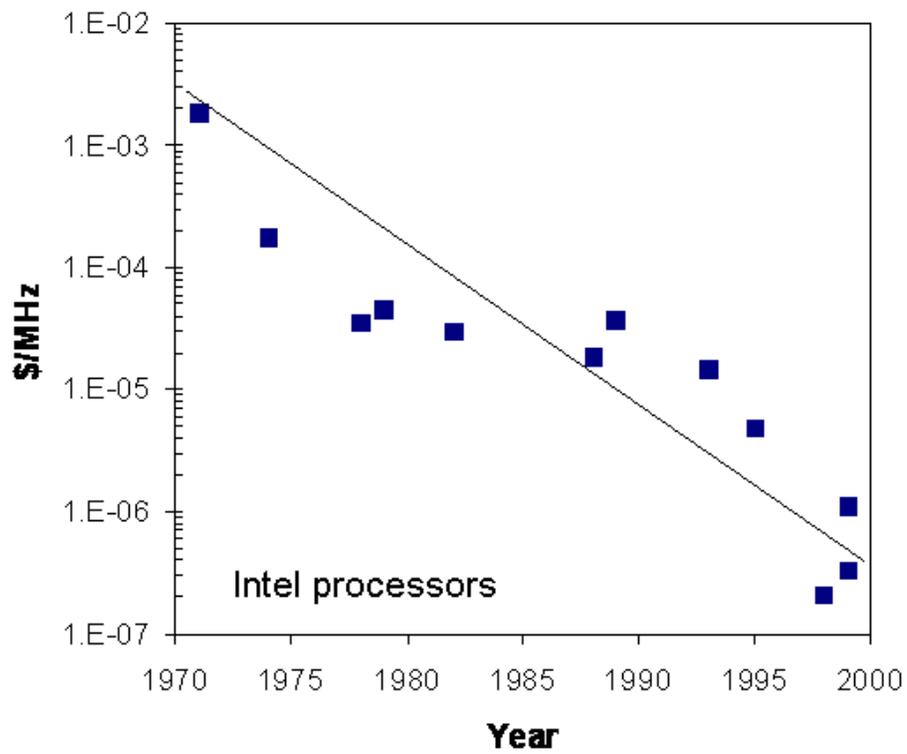
4-order of magnitude improvement in 30 years

□ Transistor Cost



3-order of magnitude reduction in 30 years

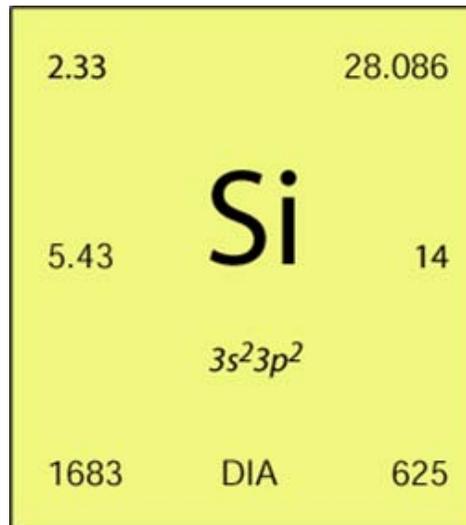
□ Cost per function



4-order of magnitude reduction in 30 years

2. Keys to the microelectronics revolution

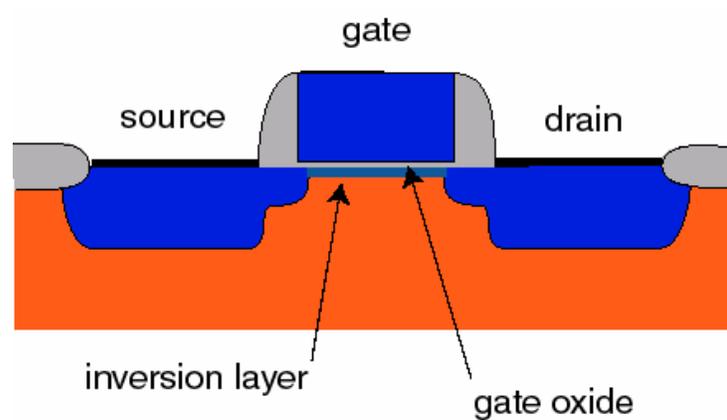
1. Silicon



- Cheap and abundant
- Amazing mechanical, chemical and electronic properties
- Probably, the material best known to humankind

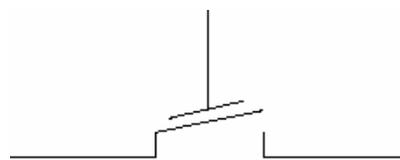
2. MOSFET

MOSFET =
Metal-Oxide-Semiconductor Field-Effect Transistor

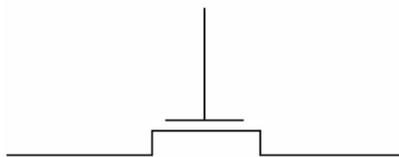


Good gain, isolation, and speed

MOSFET = switch



$V_G < V_T$ switch open

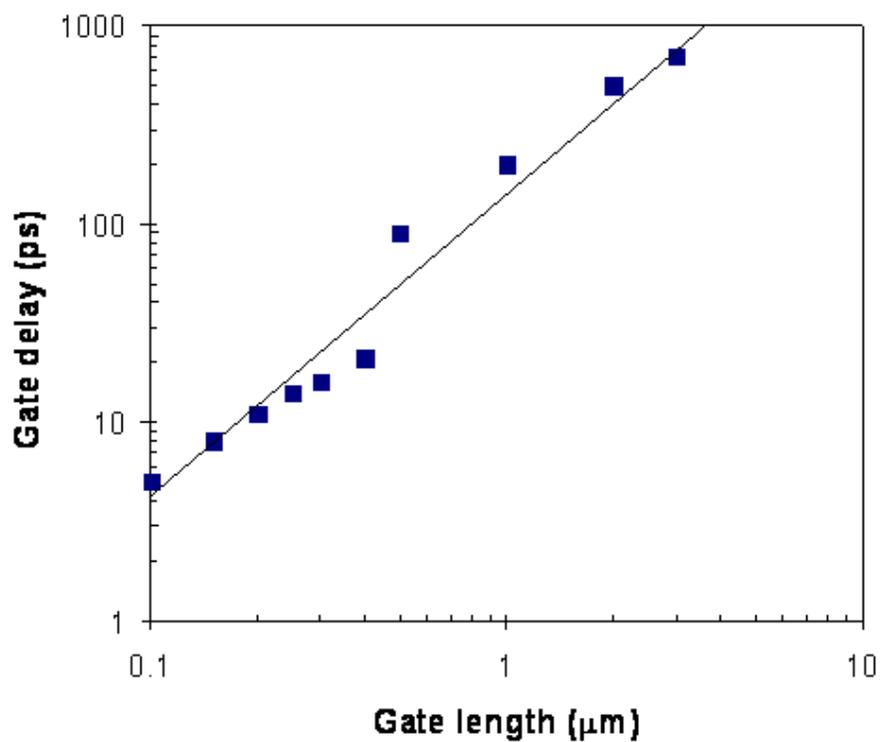


$V_G > V_T$ switch closed

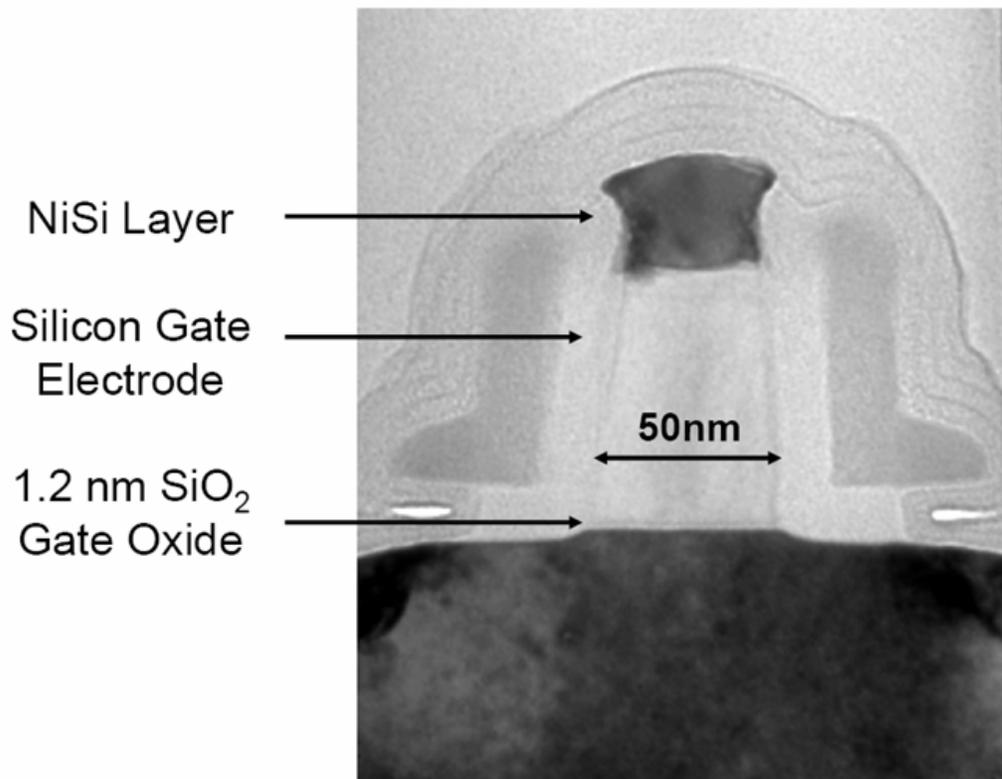
3. MOSFET scaling

MOSFET performance improves as size is decreased:

- shorter switching time
- lower power consumption



90 nm NMOS

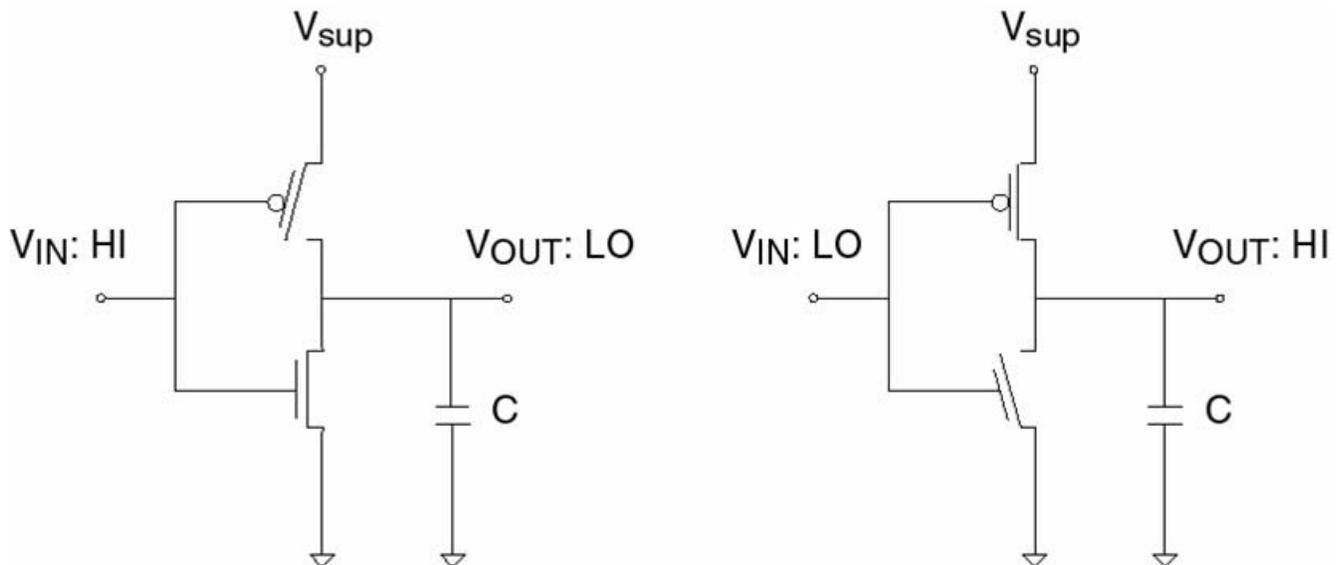


Courtesy of Intel Corporation. Used with permission.

[Picture from: <http://www.intel.com/technology/silicon/micron.htm>]

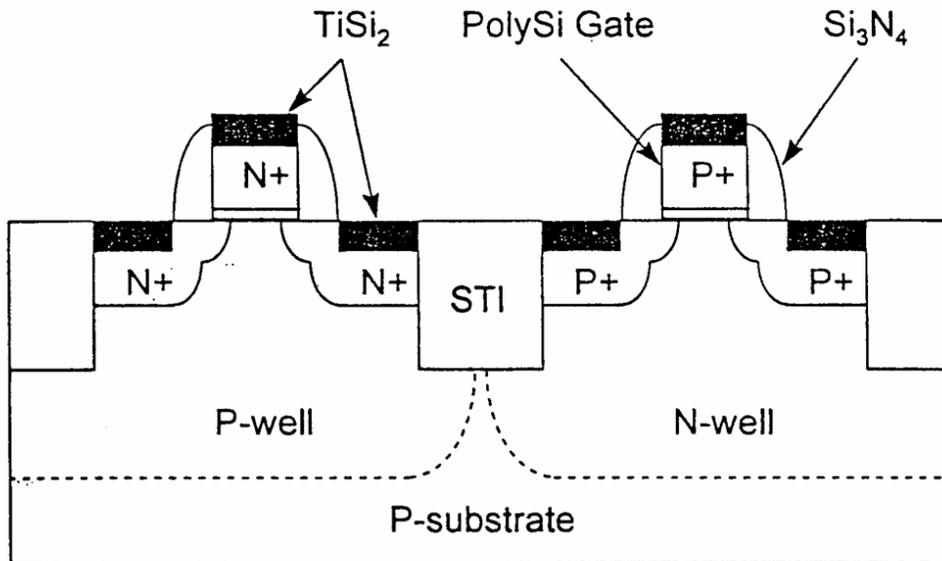
4. CMOS

CMOS = Complementary Metal-Oxide-Semiconductor



- Complementary switch activates with $V < 0$
- Logic without DC power consumption

□ NMOS and PMOS can be fabricated side-by-side in a very compact way



5. Microfabrication technology

1 Gbit DRAM from IBM. Image removed due to copyright restrictions.

- Tight integration of dissimilar devices with good isolation
- Fabrication of extremely small structures, precisely and reproducibly
- High-volume manufacturing of complex systems with high yield

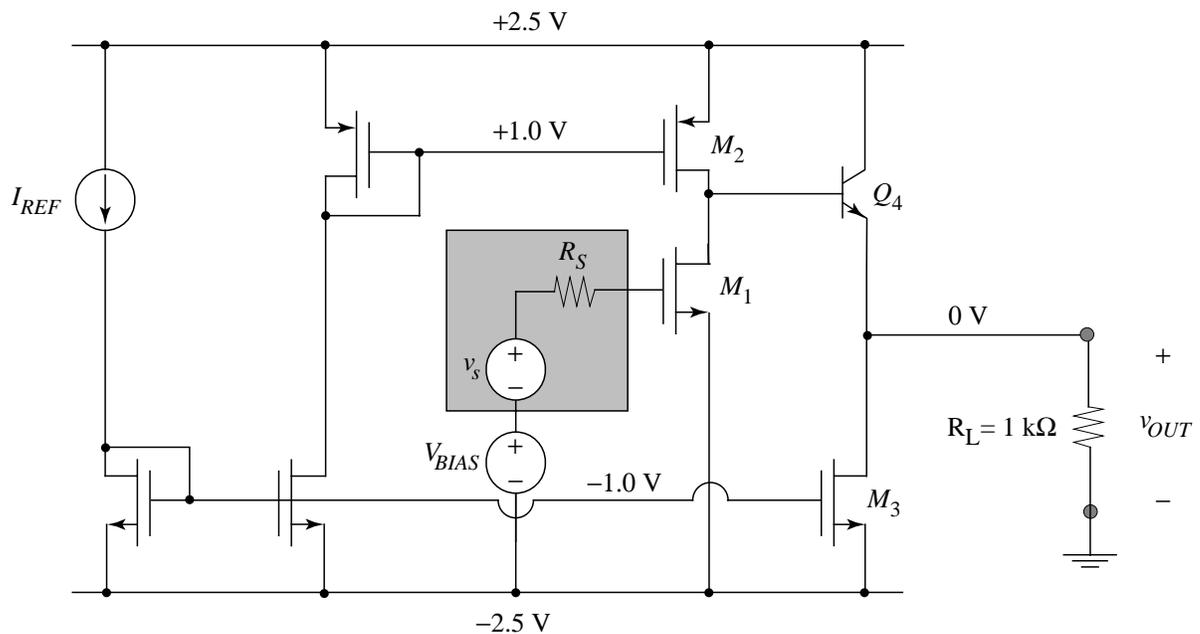
6. Circuit engineering

Simple device models that:

- are based on physics
- allow analog and digital circuit design
- permit assessment of impact of device variations on circuit performance

Circuit design techniques that:

- are tolerant to logic level fluctuations, noise and crosstalk
- are insensitive to manufacturing variations
- require little power consumption



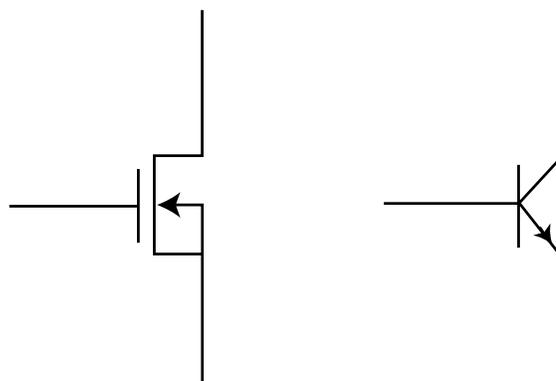
3. Contents of 6.012

Deals with microelectronic devices...

- semiconductor physics
- metal-oxide-semiconductor field-effect transistor (MOS-FET)
- bipolar junction transistor (BJT)

... and microelectronic circuits

- digital circuits (mainly CMOS)
- analog circuits (BJT and MOS)



One shouldn't work on semiconductors, that is a filthy mess; who knows if they really exist!

Wolfgang Pauli, 1931

(Nobel Prize, Physics, 1945)

To the electron may it never be of any use to anybody.

favorite toast at annual dinners
at Cavendish Laboratory,
early 1900s