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6.012
Microelectronic Devices and Circuits

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Lecture 1 – 6.012 Overview

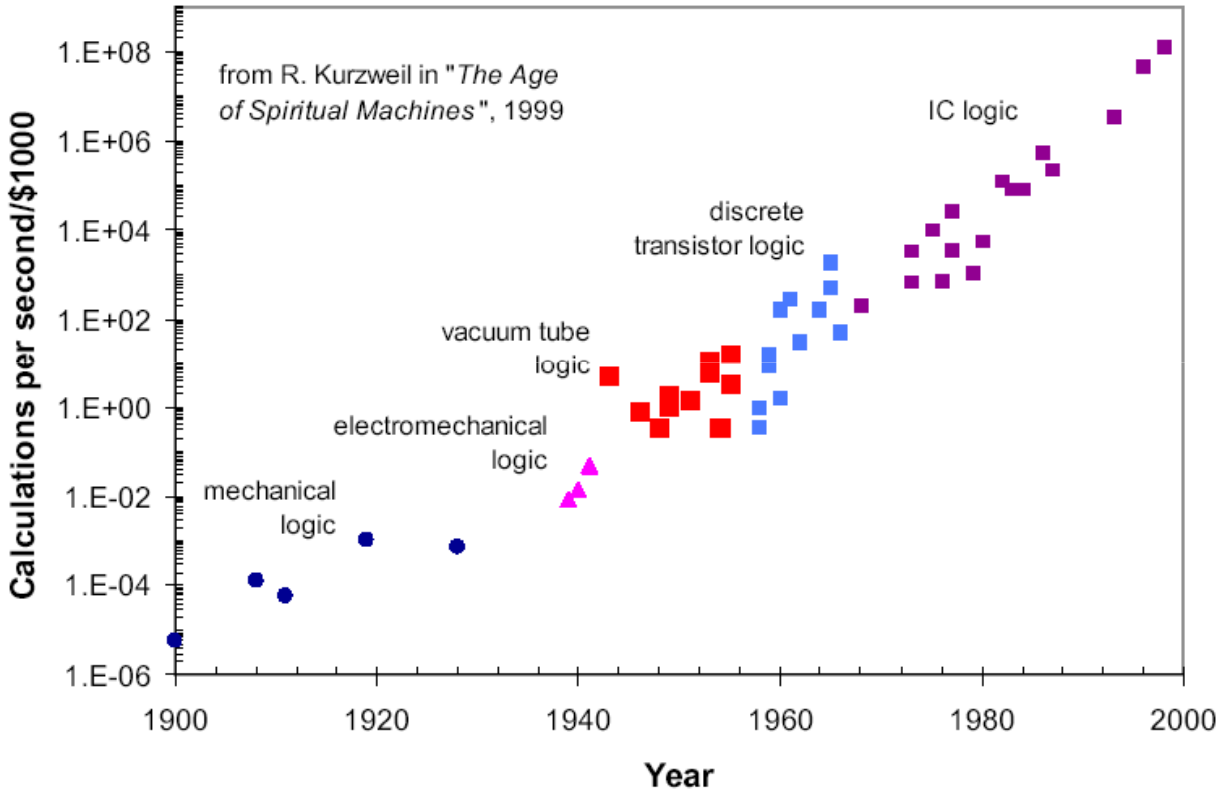
- Contents:
  - Overview of 6.012
- Reading Assignment:
  - Howe and Sodini, Ch. 2

Overview of 6.012

- Introductory subject to microelectronic devices and circuits

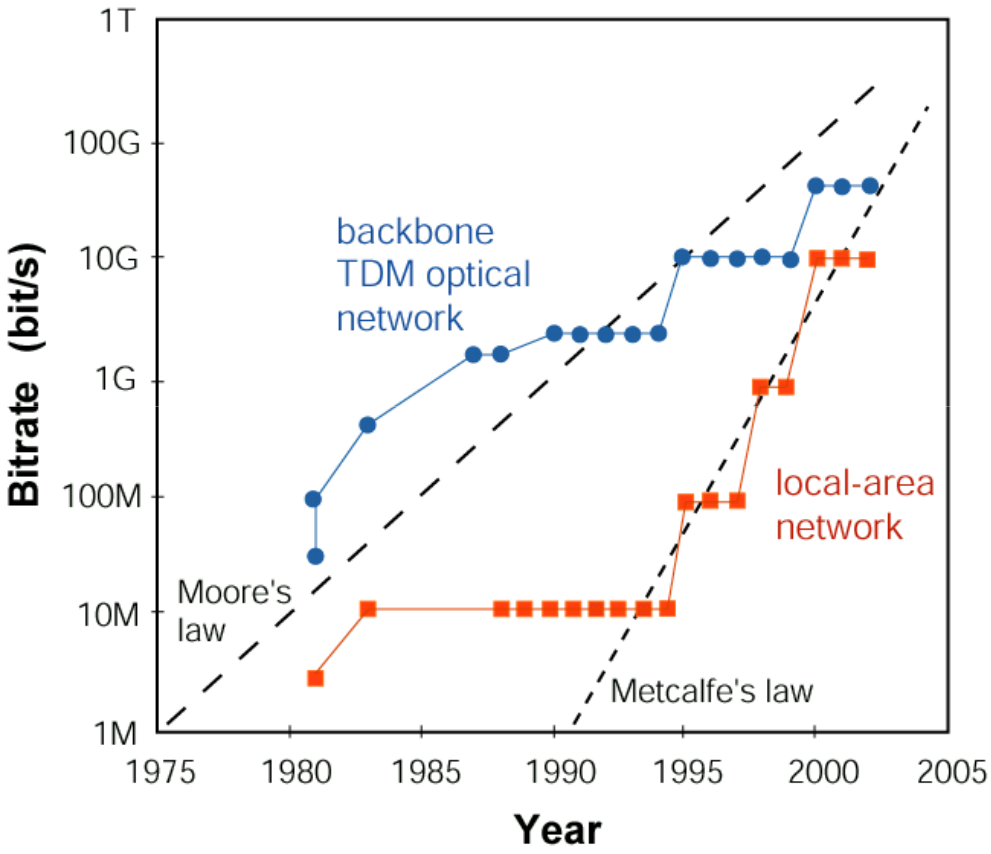
- Microelectronics is the cornerstone of:
  - Computer revolution
  - Communications revolution
  - Consumer Electronics revolution

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.

Microelectronics: cornerstone of consumer electronics revolution

Images of consumer electronics (cell phones, digital cameras, PDA) removed due to copyright restrictions.

Low power electronics enabling a variety of portable devices

Si digital microelectronics today

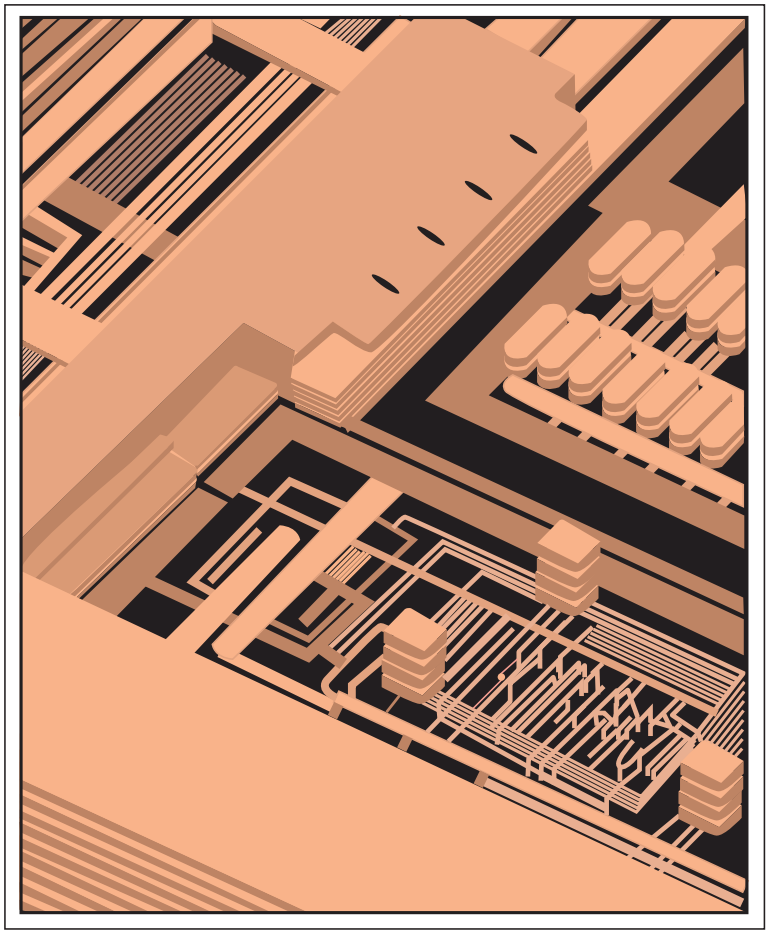
Image of Pentium microprocessor removed due to copyright restrictions.

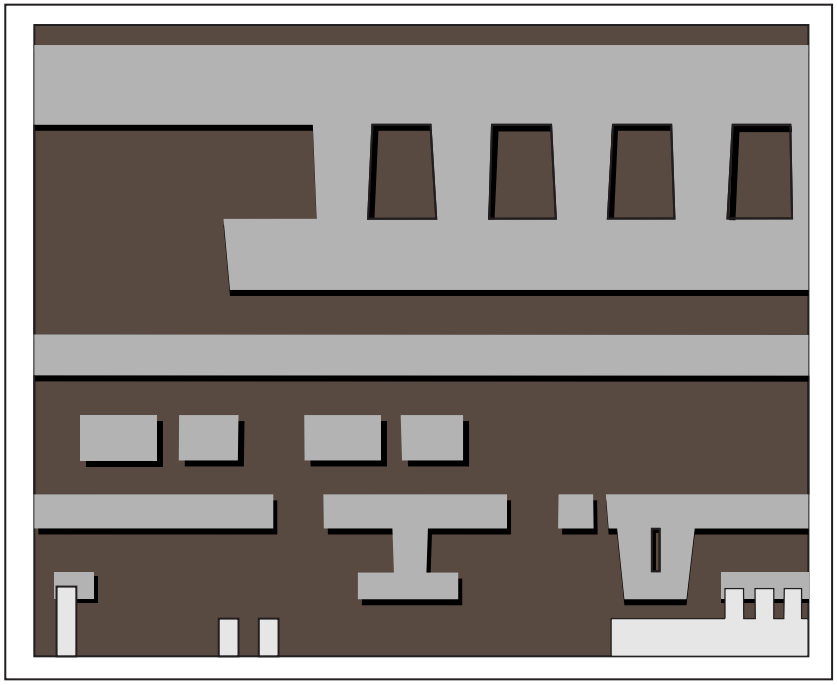
Take the cover off a microprocessor. What do you see?

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

Intel's Pentium IV

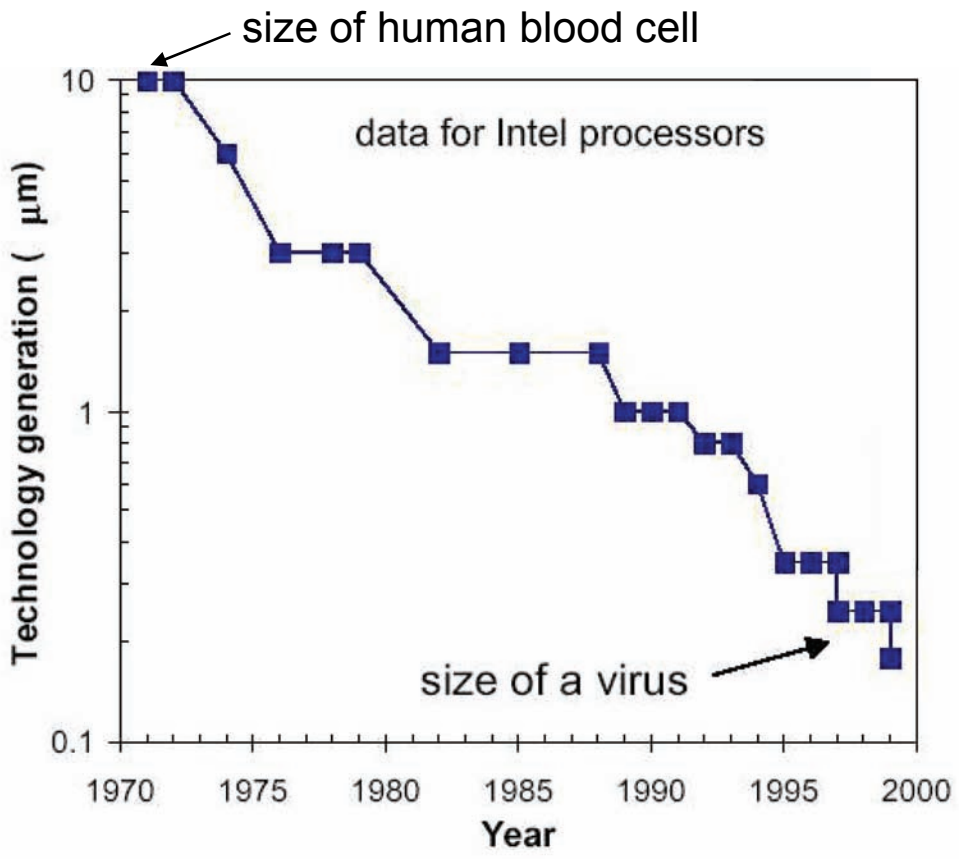
Interconnects





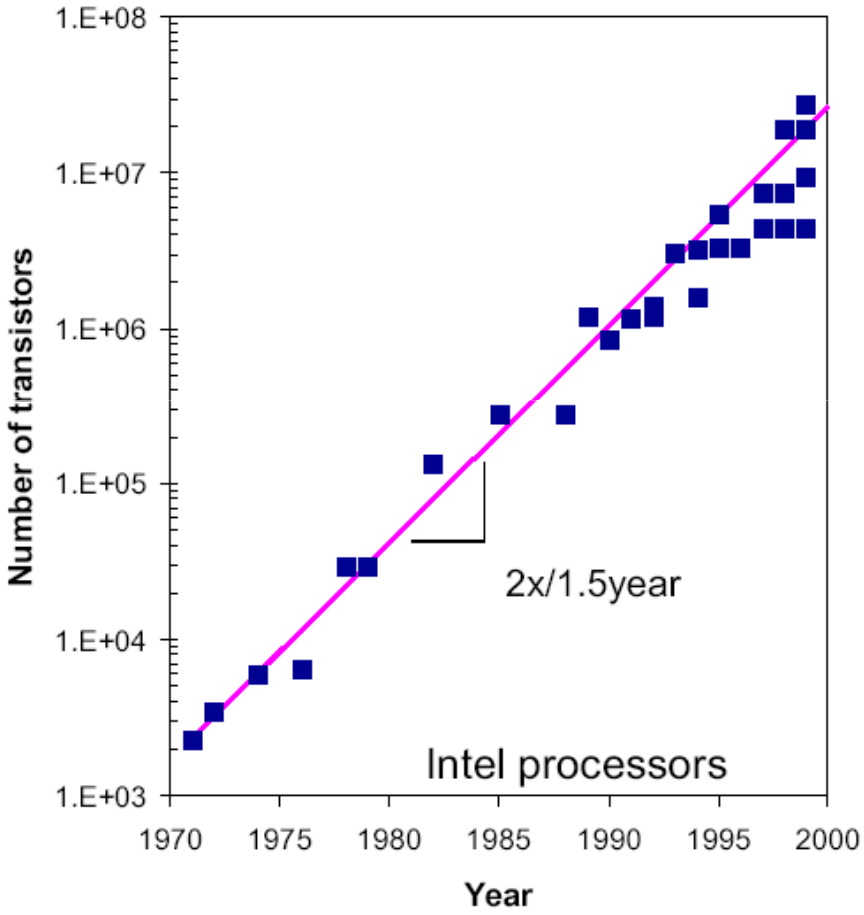
Today, as many as 7 levels of interconnect using Cu.

Transistor size scaling



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

4-orders of magnitude improvement in 30 years.

Benefits of increasing transistor integration

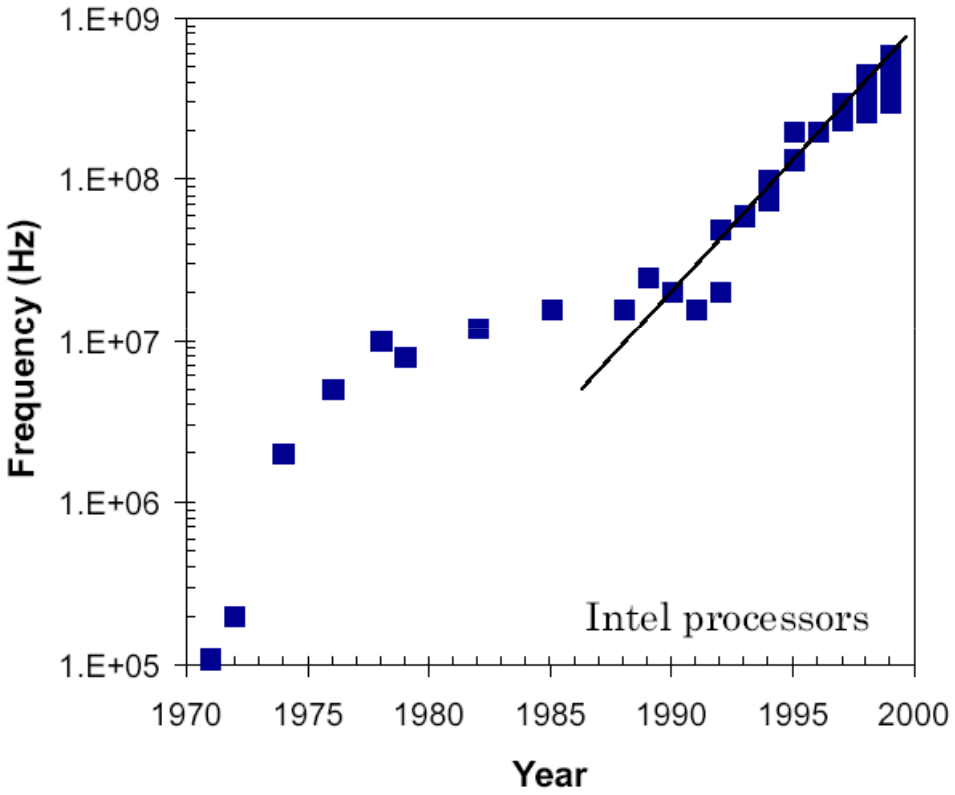
Exponential improvements in:

- system performance
- cost-per-function,
- power-per-function, and
- system reliability.

Image of microprocessor removed due to copyright restrictions.

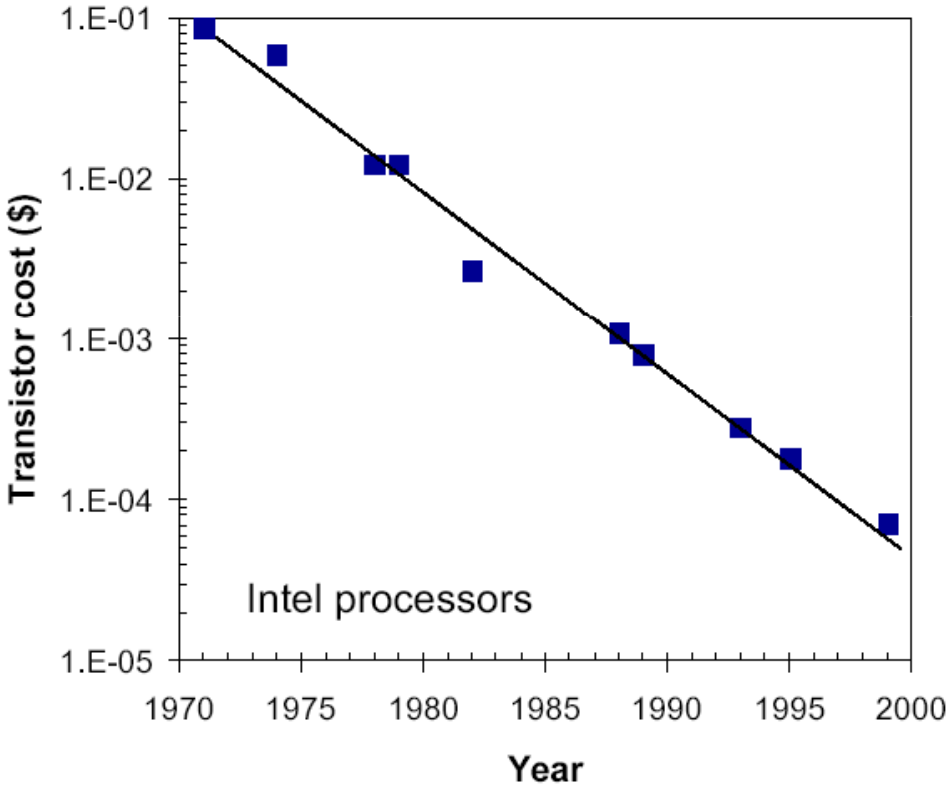
Experimental SOI microprocessor from IBM

Clock speed



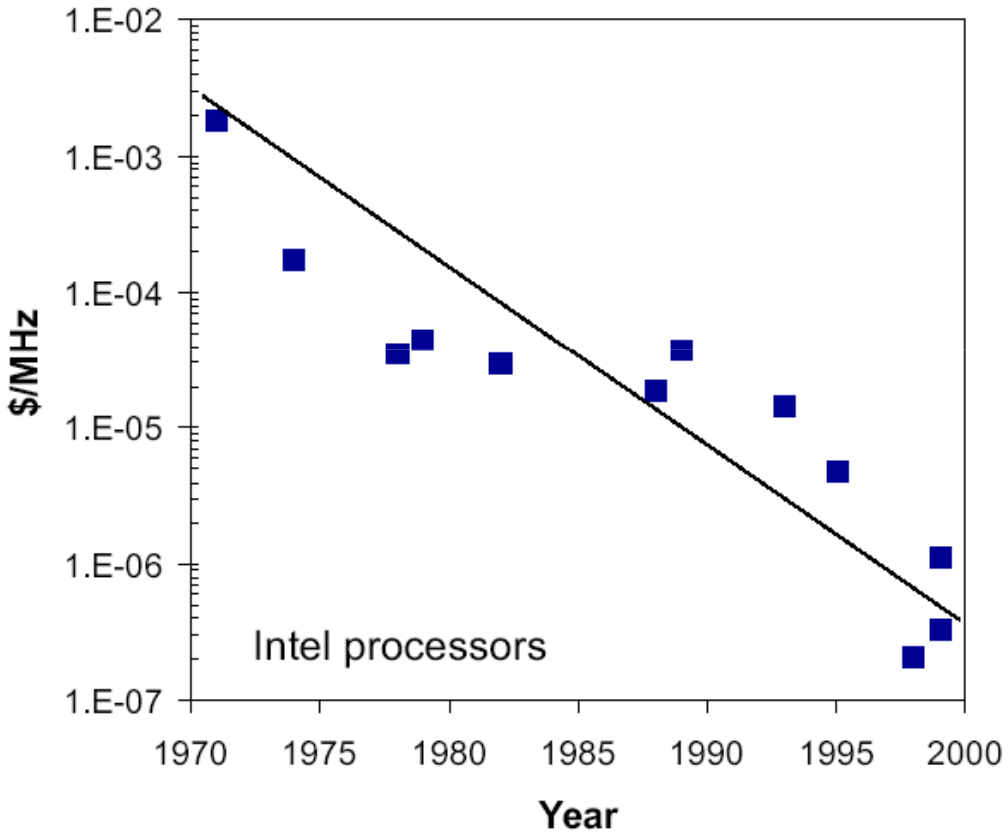
4-orders of magnitude improvement in 30 years.

Transistor cost



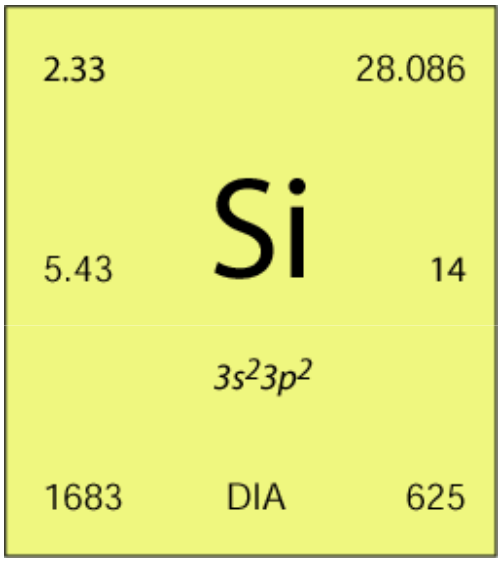
3-order of magnitude reduction in 30 years.

Cost per function



4-order of magnitude reduction in 30 years.

Keys to success of digital microelectronics:
I. Silicon

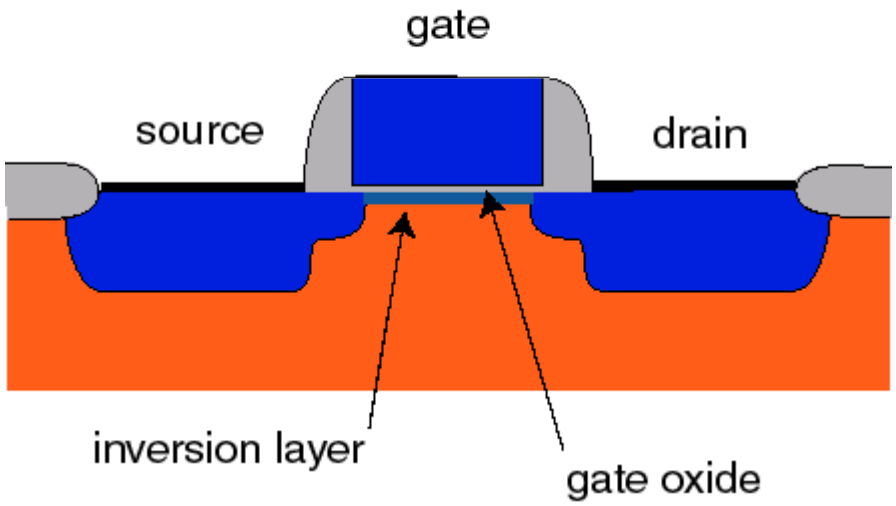


- Cheap and abundant
- Amazing mechanical, chemical and electronic properties
- Probably, the material best known to humankind

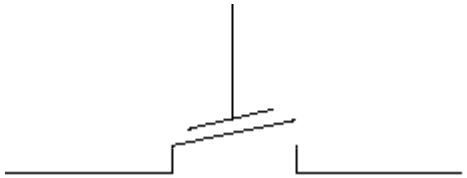
Keys to success of digital microelectronics:
II. MOSFET

Metal-Oxide-Semiconductor

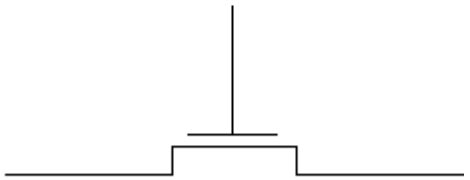
Field-Effect Transistor



MOSFET = switch



$V_G < V_T$ switch open



$V_G > V_T$ switch closed

Good gain, isolation, and speed

Modern MOSFET structure

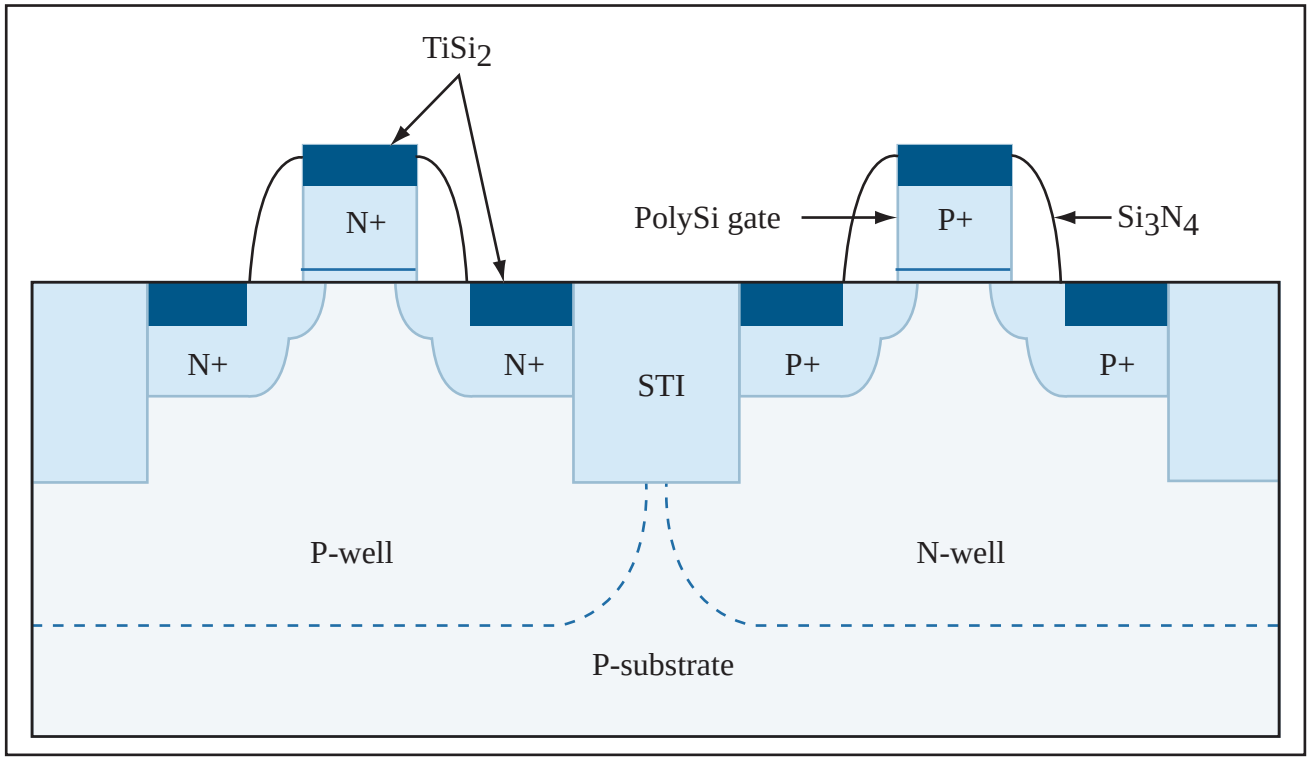
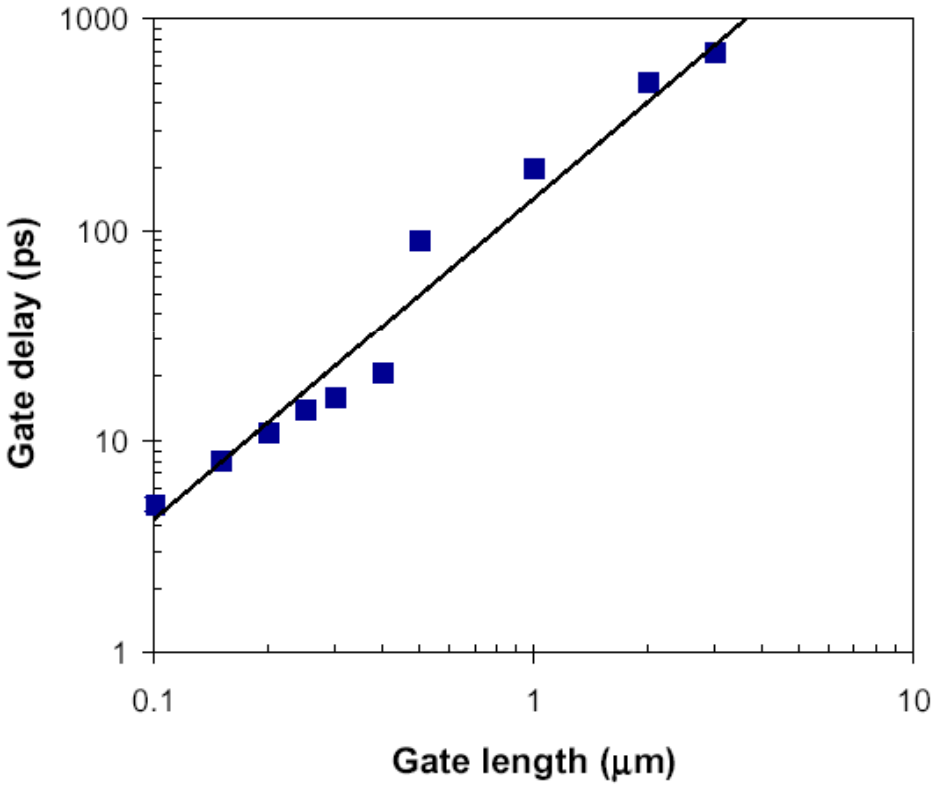


Figure by MIT OpenCourseWare.

Keys to success of digital microelectronics:
III. MOSFET scaling

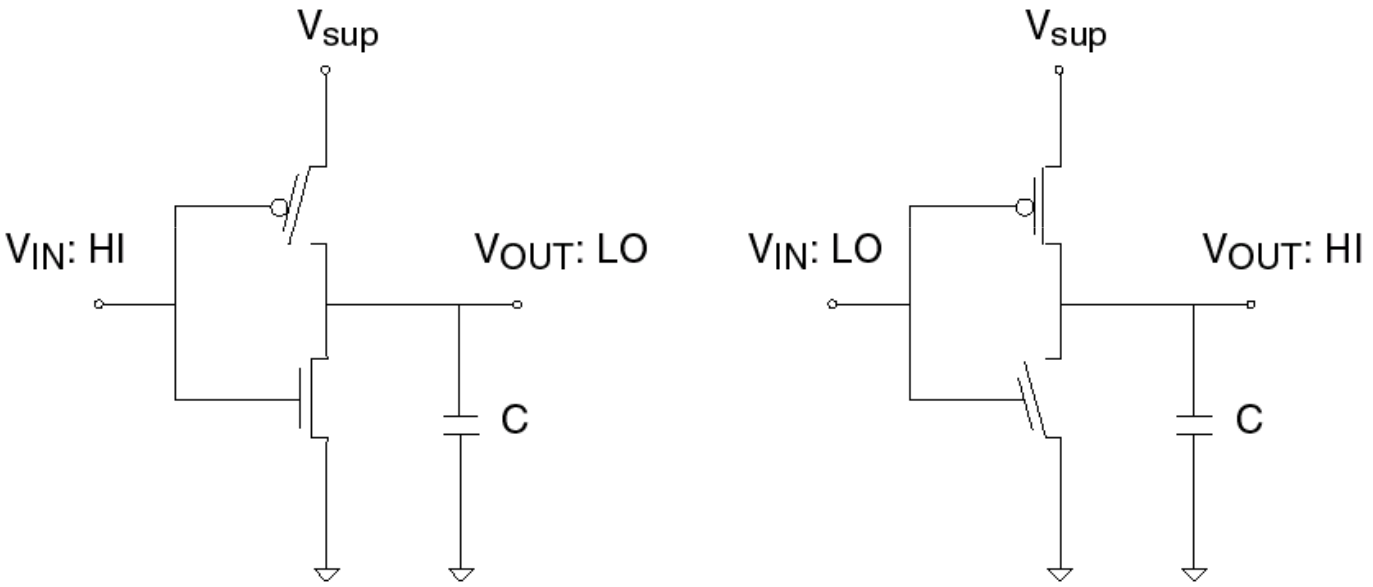


MOSFET performance improves as size is decreased:

- Shorter switching time
- Lower power consumption

Keys to success of digital microelectronics:
IV. CMOS

CMOS: Complementary Metal-Oxide-Semiconductor



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

Keys to success of digital microelectronics:
V. Microfabrication technology

Image of DRAM removed due to copyright restrictions.

1 Gbit DRAM from IBM

- 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.

Keys to success of digital microelectronics:
VI. 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

Content of 6.012

- Deals with **microelectronic devices**
  - Semiconductor physics
  - Metal-oxide-semiconductor field-effect transistor (MOSFET)
  - Bipolar junction transistor (BJT)

- Deals with **microelectronic circuits**
  - Digital circuits (mainly CMOS)
  - Analog circuits (BJT and MOS)

- The interaction of devices and circuits captured by models

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