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# 6.012
# Microelectronic Devices and Circuits

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# Lecture 1 – 6.012 Overview

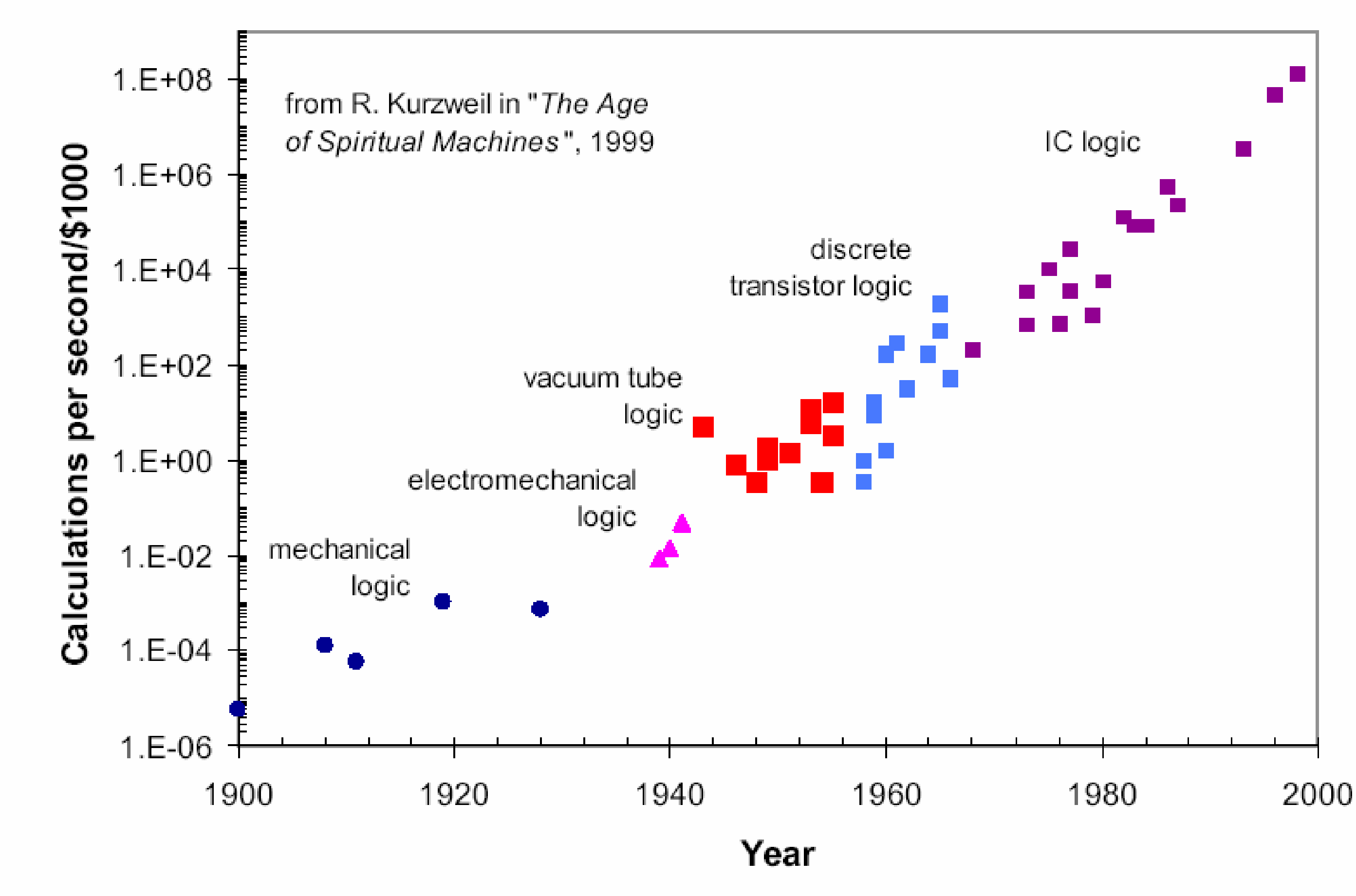
- Contents:
  - Overview of 6.012
- Reading Assignment:
  - Howe and Sodini, Ch. 1

# Overview of 6.012

- Introductory subject to microelectronic devices and circuits

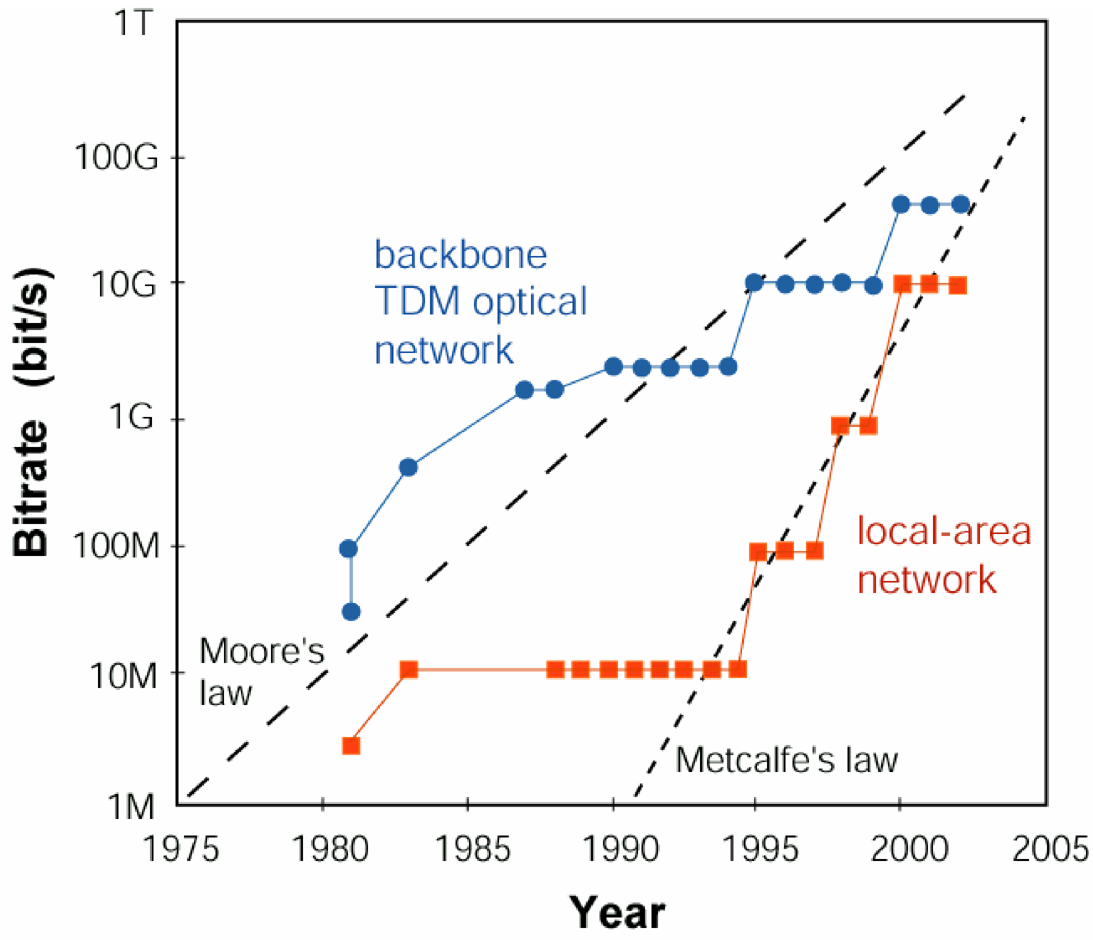
- Microelectronics is the cornerstone of:
  - Computer revolution
  - Communications revolution
  - Consumer Electronics revolution

# 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


Low power electronics enabling a variety of portable devices

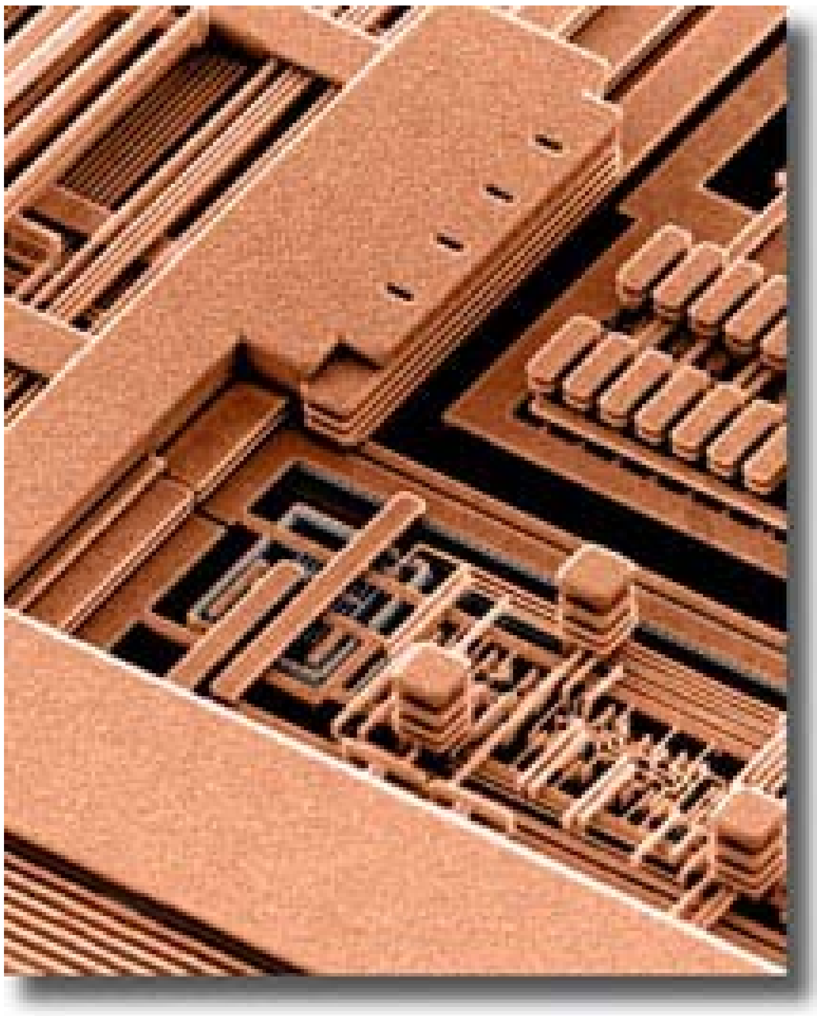
# Si digital microelectronics today

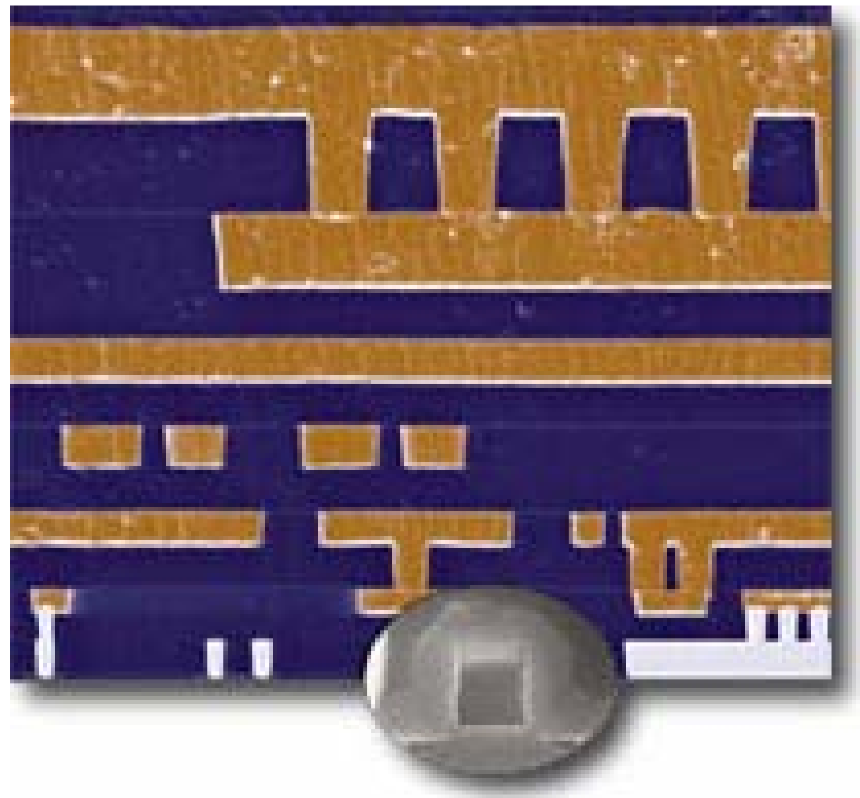
**Take the cover off a microprocessor. What do you see?**

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

Intel's Pentium IV

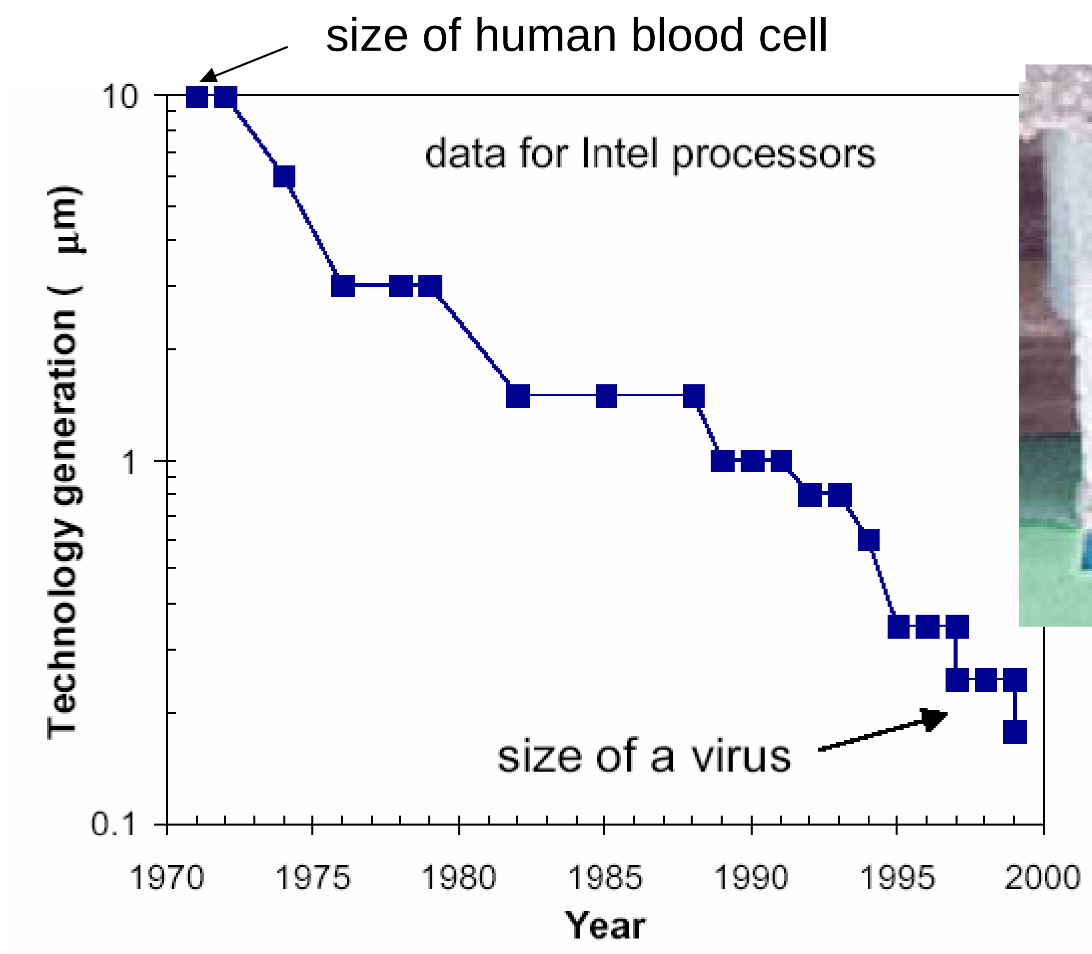
# Interconnects

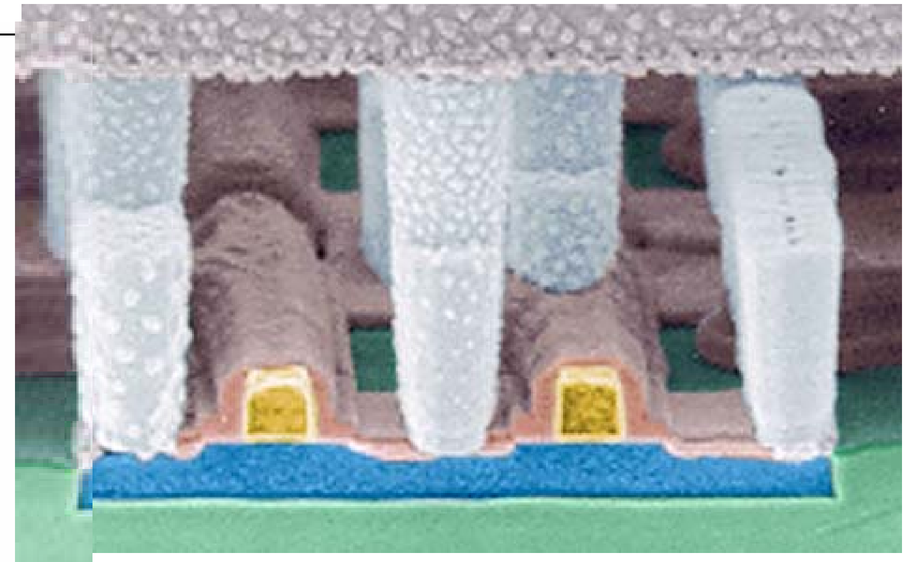


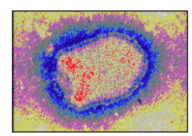


Today, as many as 7 levels of interconnect using Cu.

# Transistor size scaling



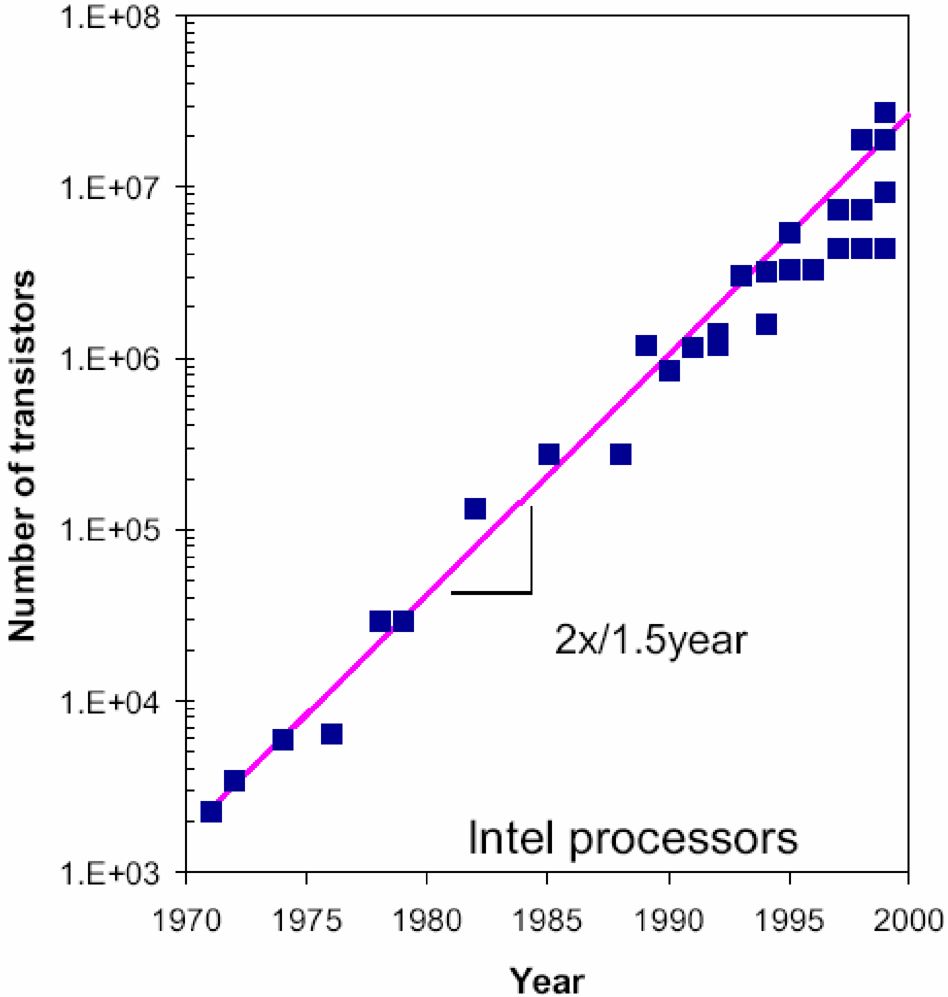





Rabies virus at same scale

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

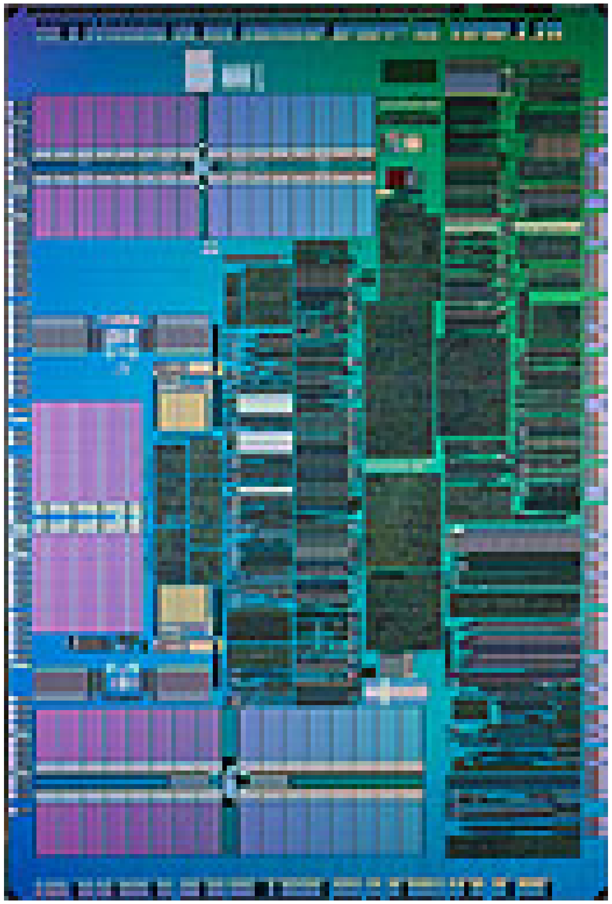
# Evolution of transistor density




**Moore's Law**: doubling of transistor density every 1.5 years

4-orders of magnitude improvement in 30 years.

# Benefits of increasing transistor integration

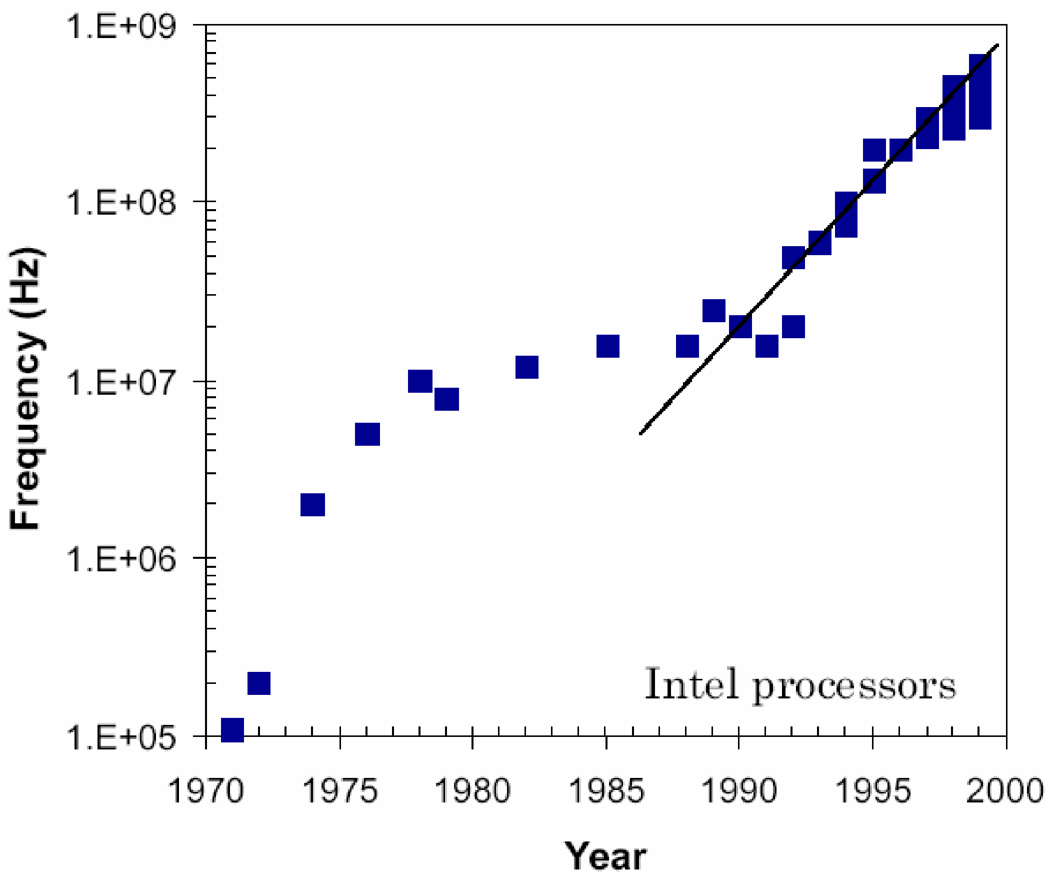


Experimental SOI microprocessor from IBM

Exponential improvements in:

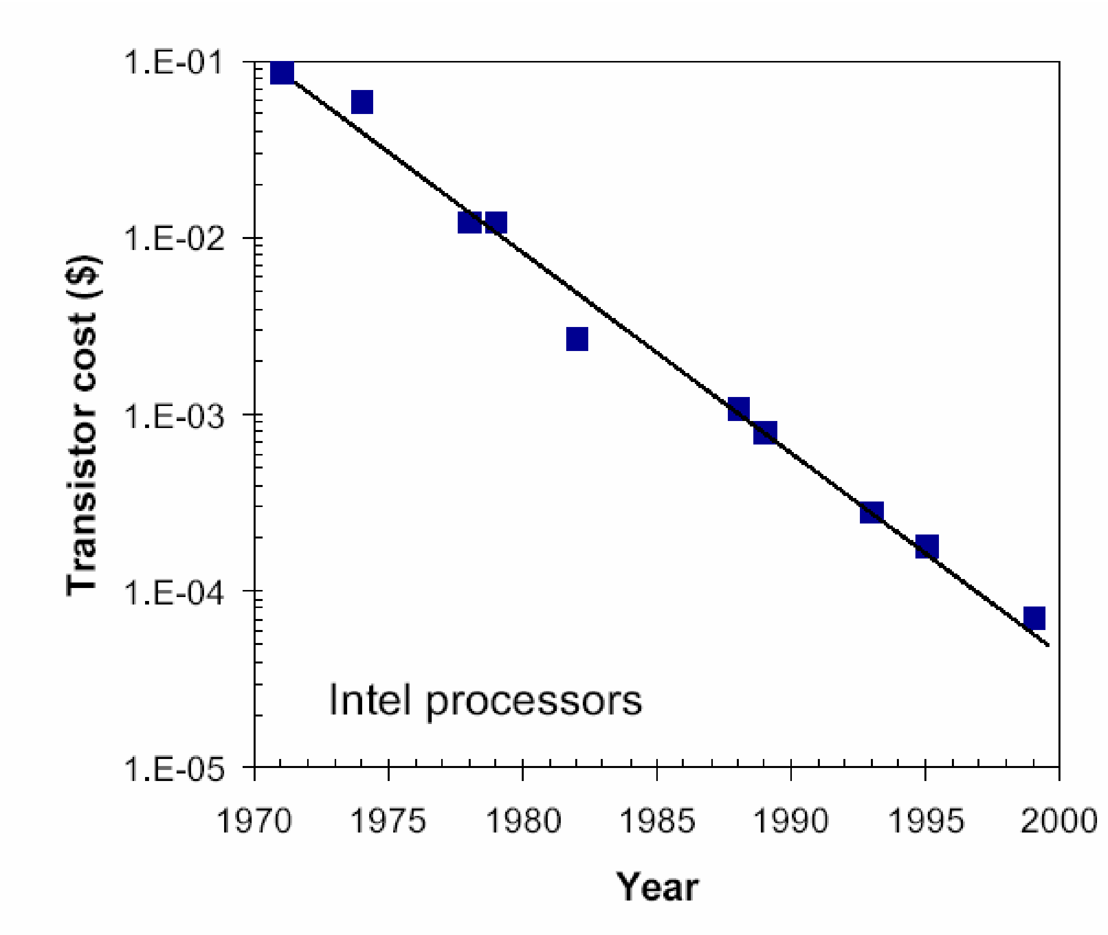
- system performance
- cost-per-function,
- power-per-function, and
- system reliability.

# Clock speed



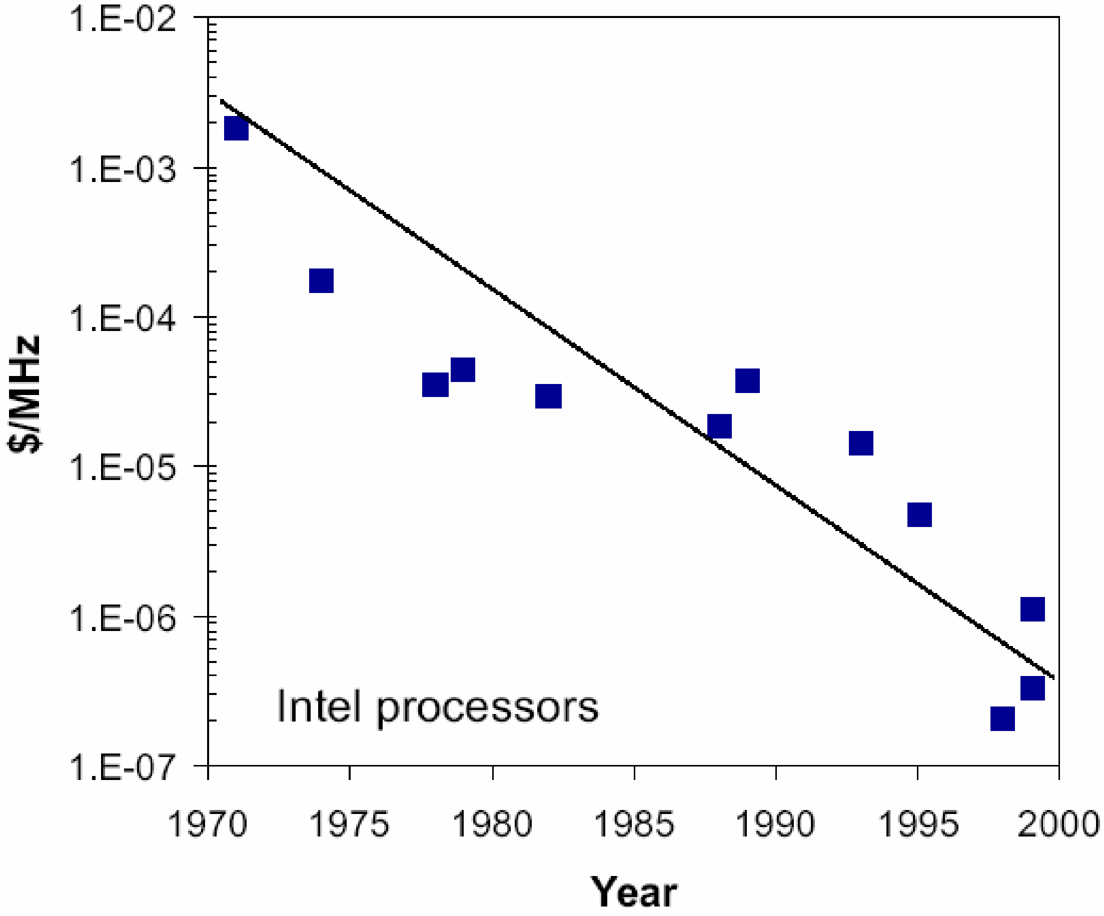

4-orders of magnitude improvement in 30 years.

# Transistor cost



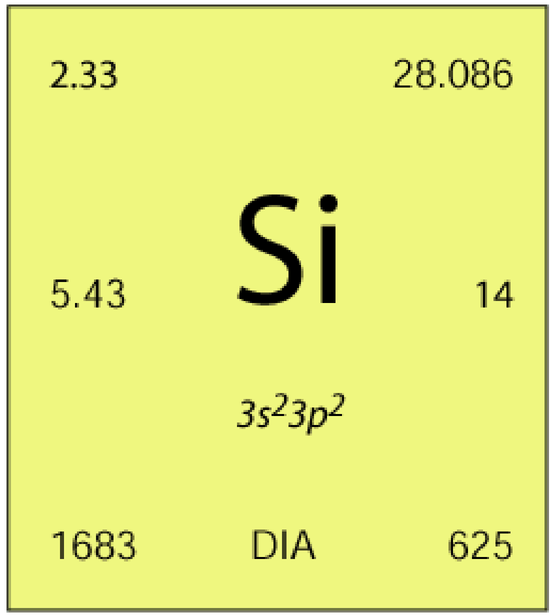

3-order of magnitude reduction in 30 years.

# Cost per function




4-order of magnitude reduction in 30 years.

# Keys to success of digital microelectronics:
# I. Silicon

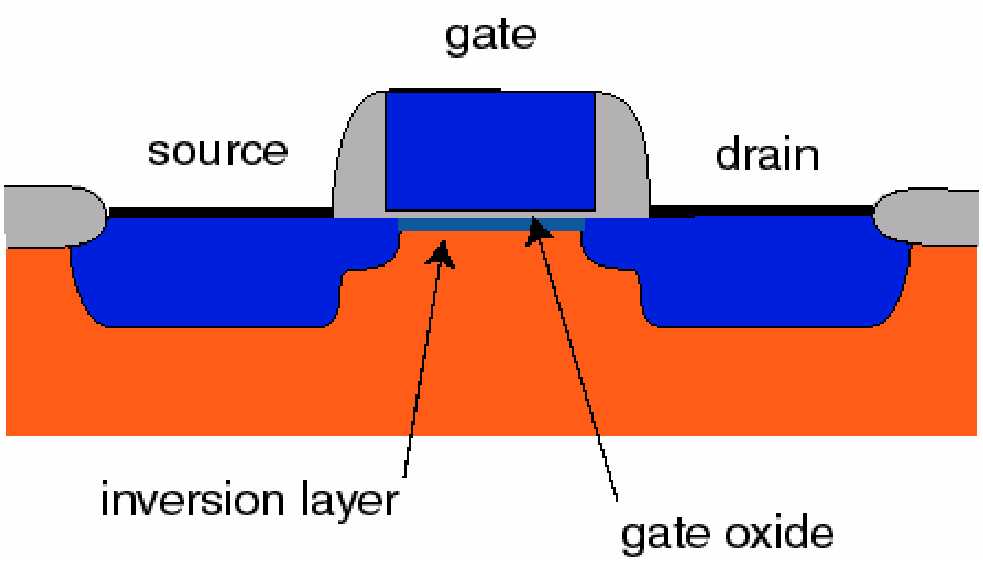



- Cheap and abundant
- Amazing mechanical, chemical and electronic properties
- Probably, the material best known to humankind

# Keys to success of digital microelectronics:
# II. MOSFET

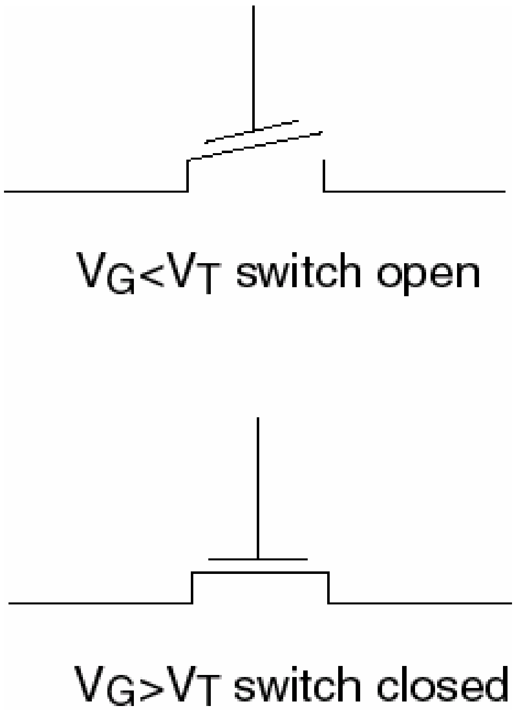
Metal-Oxide-Semiconductor

Field-Effect Transistor

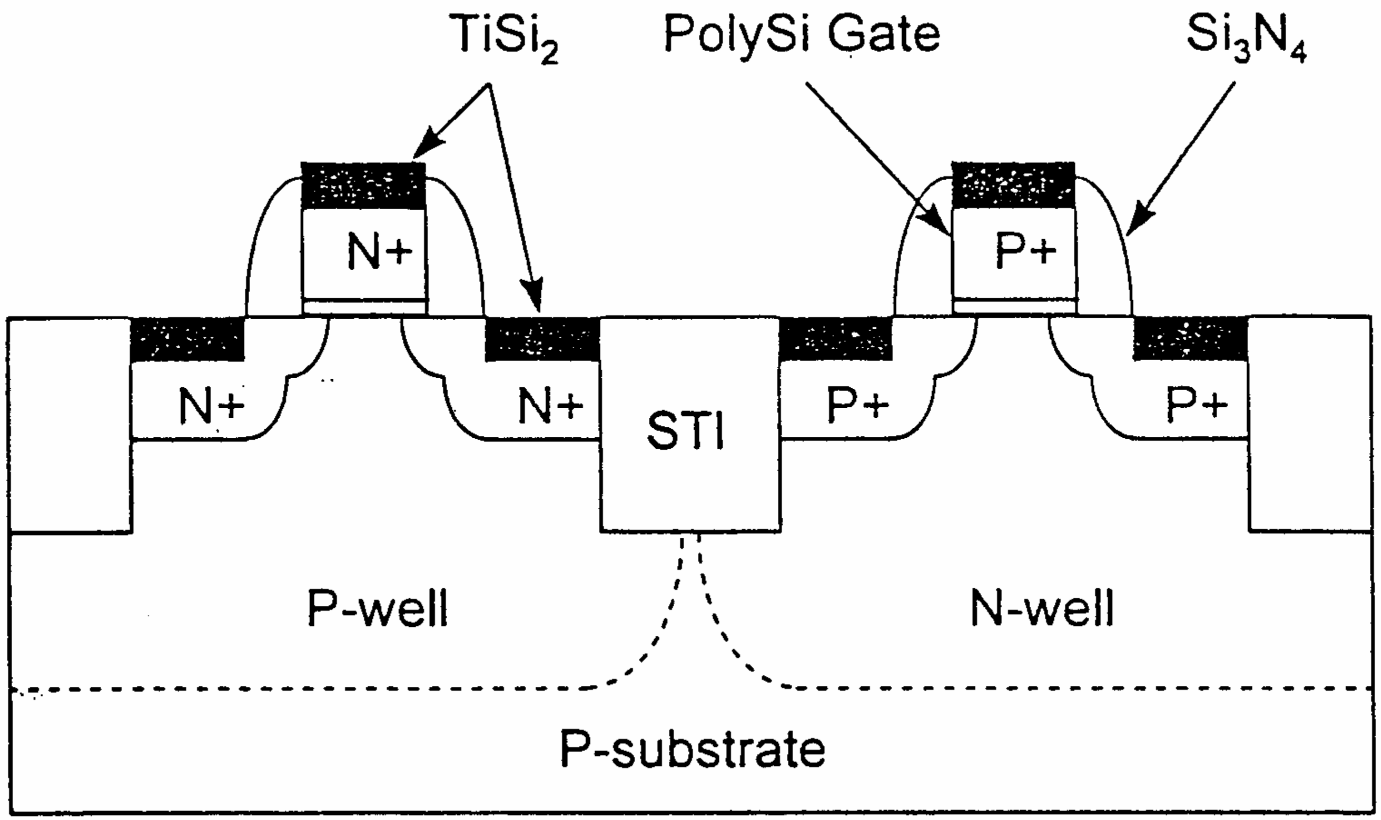



Good gain, isolation, and speed

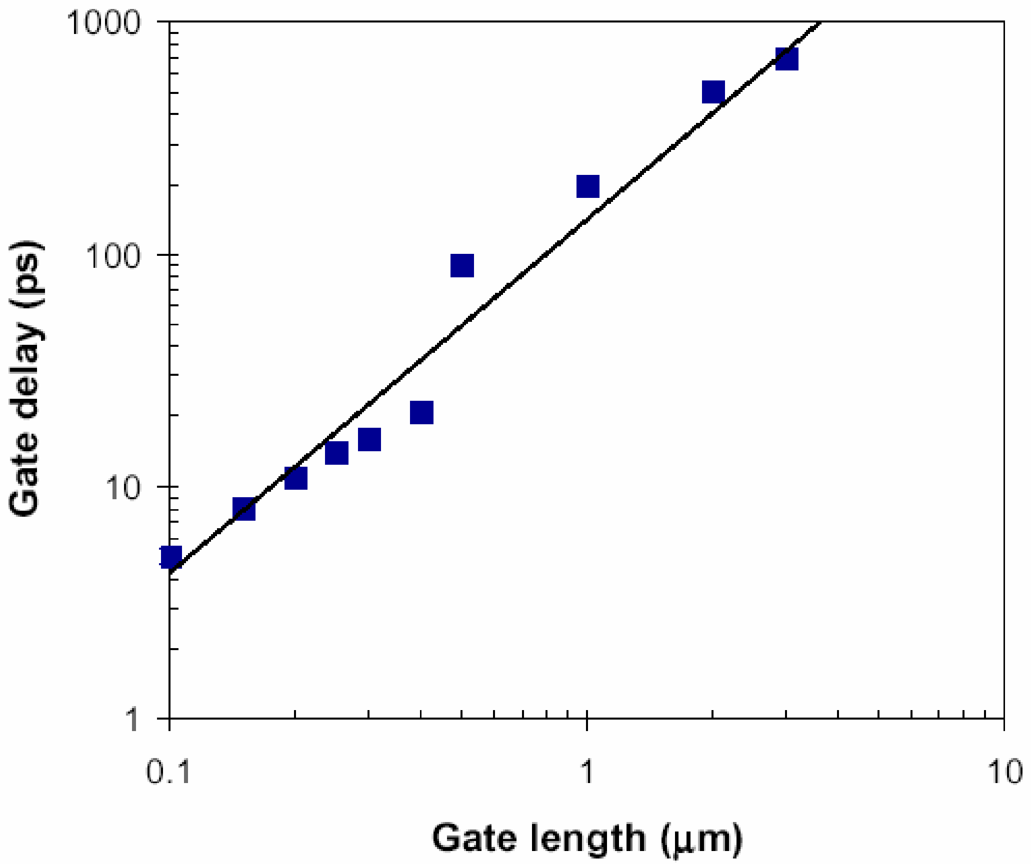
MOSFET = switch



# Modern MOSFET structure



# Keys to success of digital microelectronics:
# III. MOSFET scaling

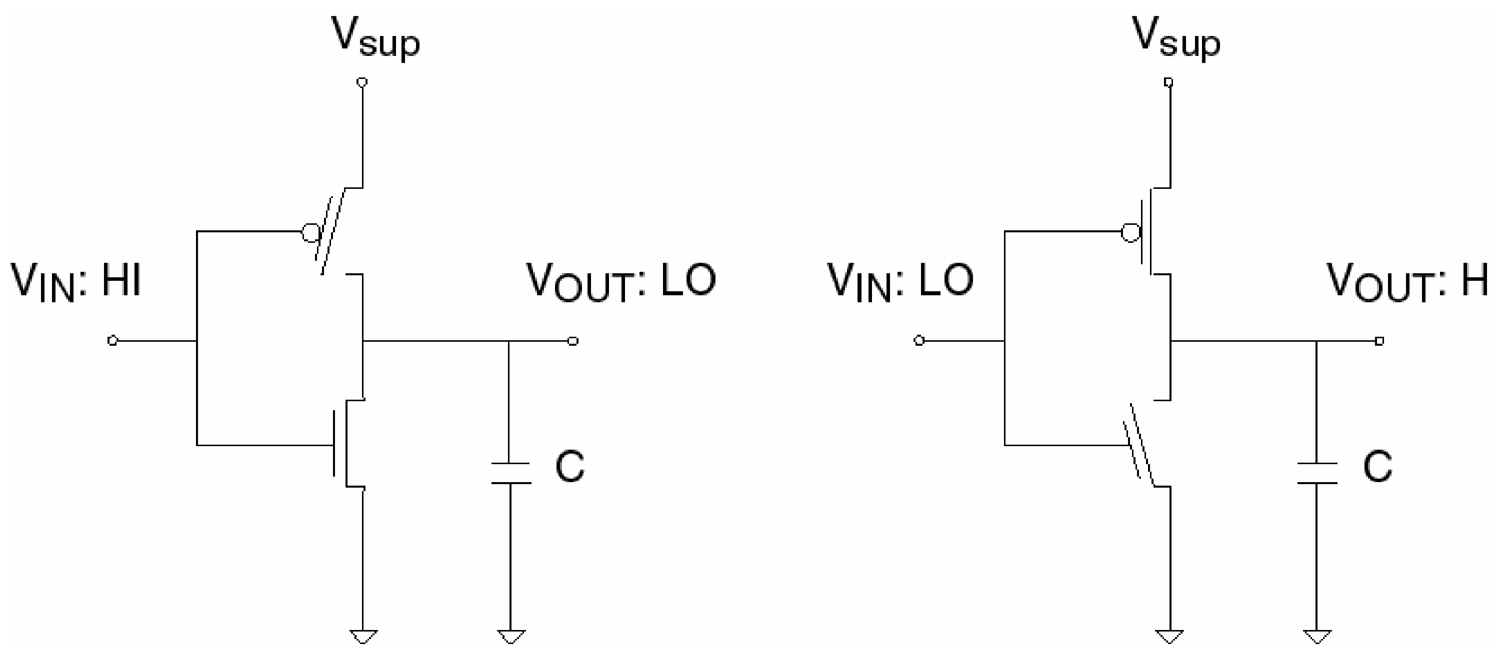



MOSFET performance improves as size is decreased:

- Shorter switching time
- Lower power consumption

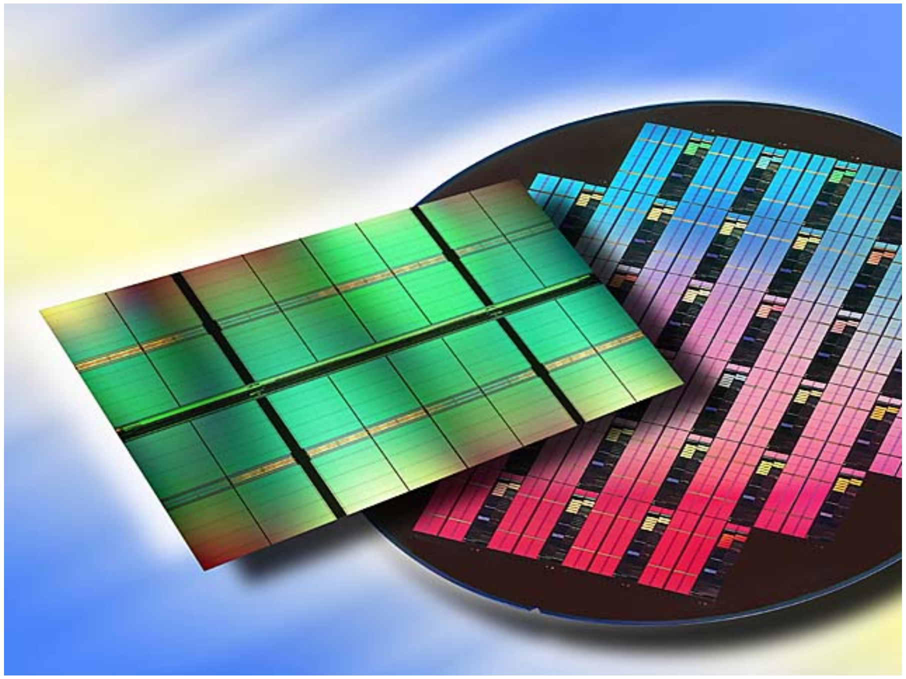
# Keys to success of digital microelectronics: IV. CMOS

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



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