

MIT, Spring 2001

**6.012**

**Microelectronic Devices and Circuits**

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# **Lecture 1 – 6.012 overview**

**February 6, 2001**

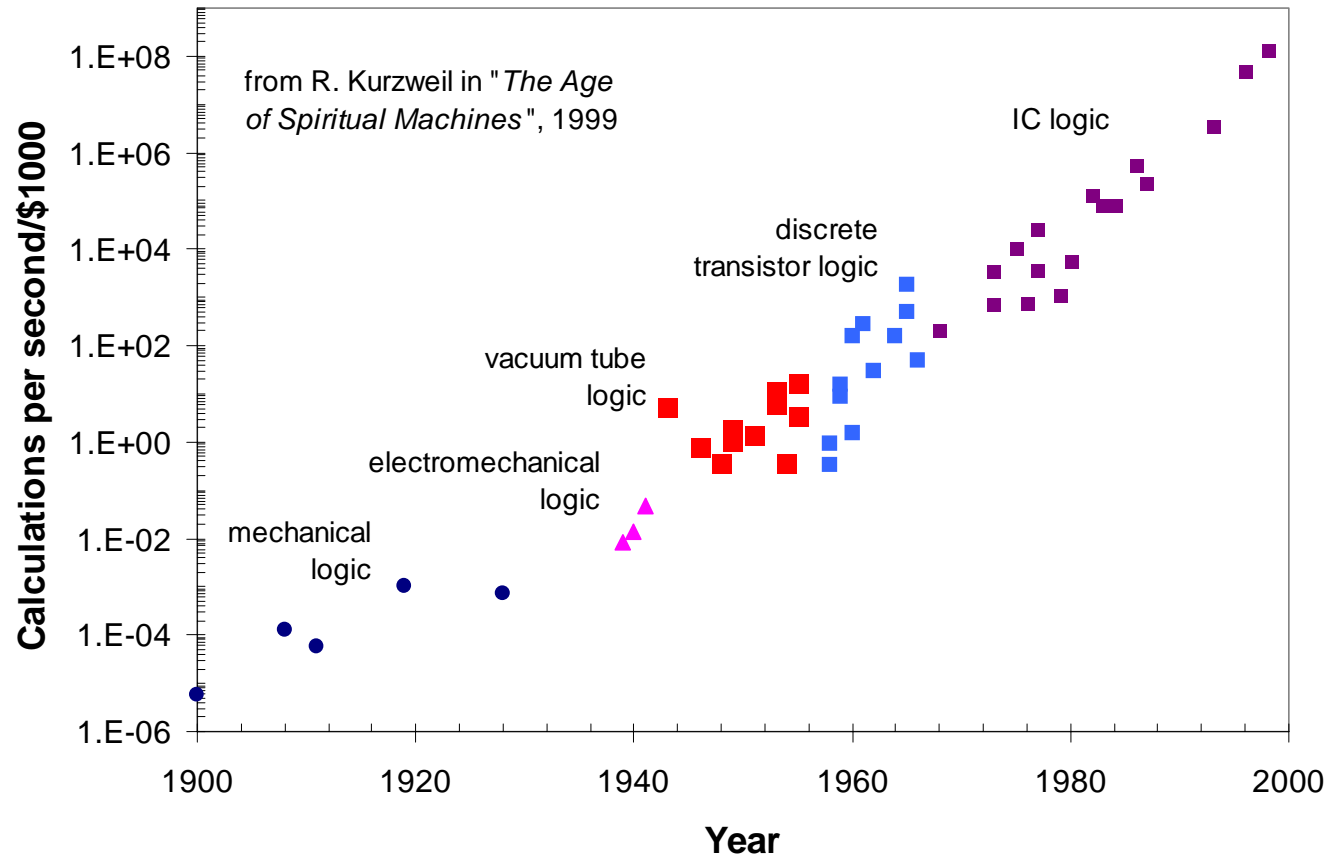
- **Contents:**
  - Overview of 6.012
- **Reading Assignment:**
  - Howe and Sodini, Ch. 1



# Overview of 6.012

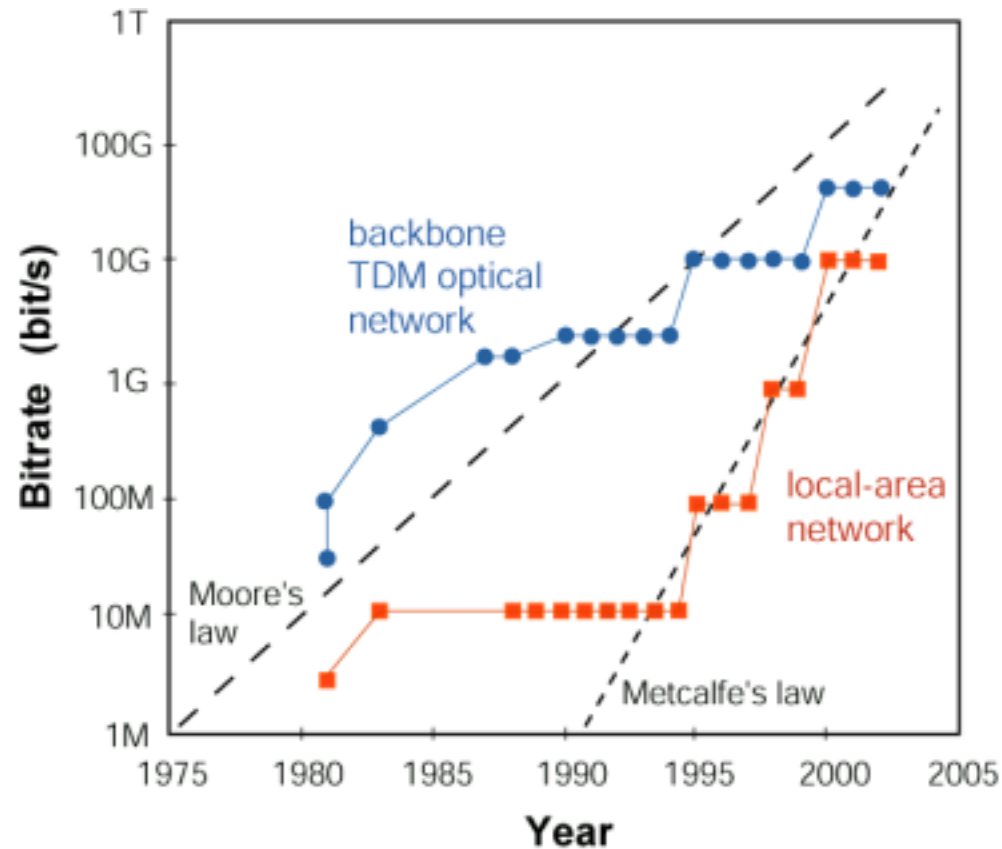
- Introductory subject to microelectronic devices and circuits
- Microelectronics is cornerstone of:
  - Computer revolution
  - Communications revolution

# 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

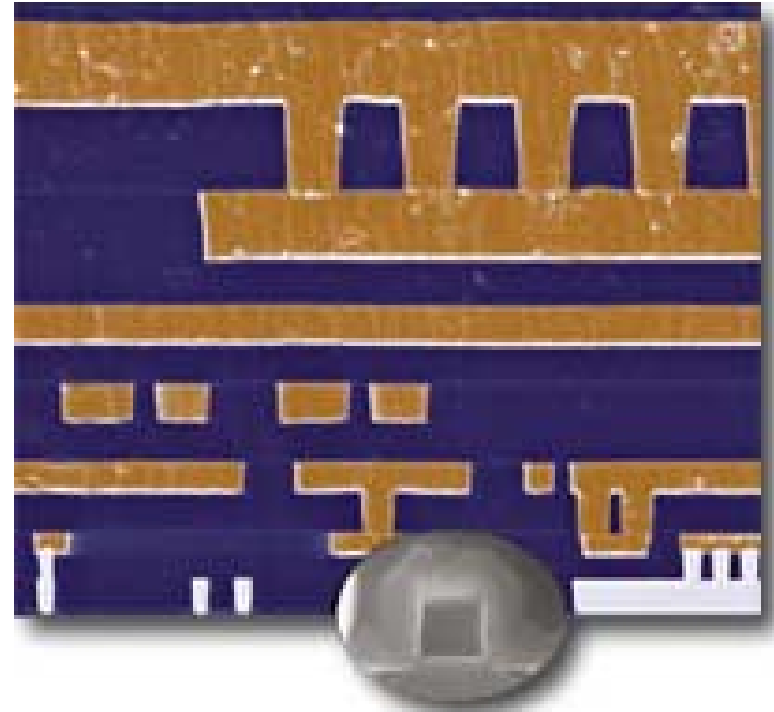
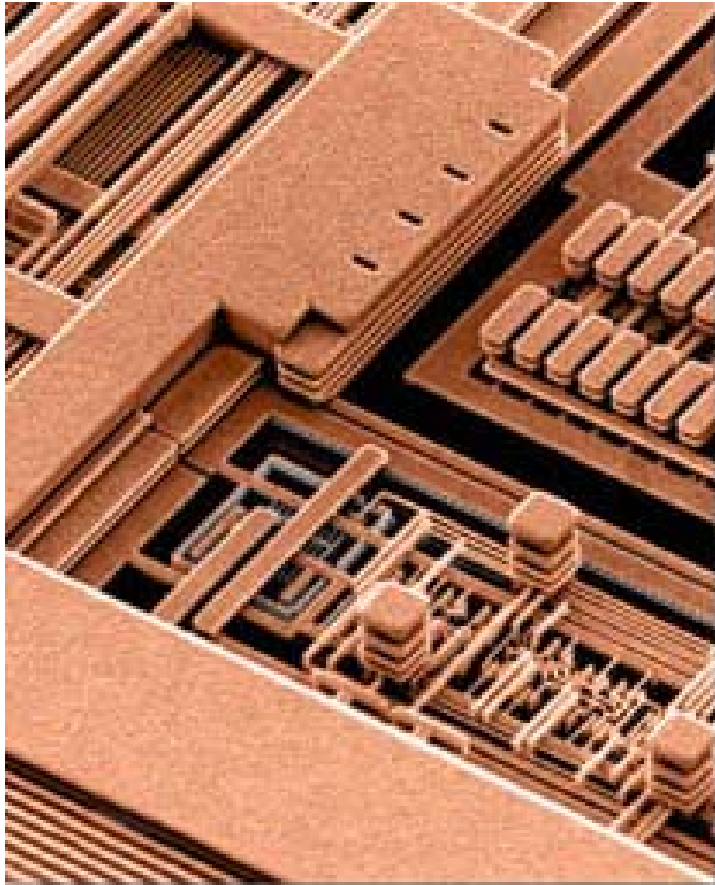


**Take the cover off a microprocessor. What do you see?**

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

Intel's Pentium IV

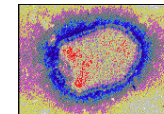
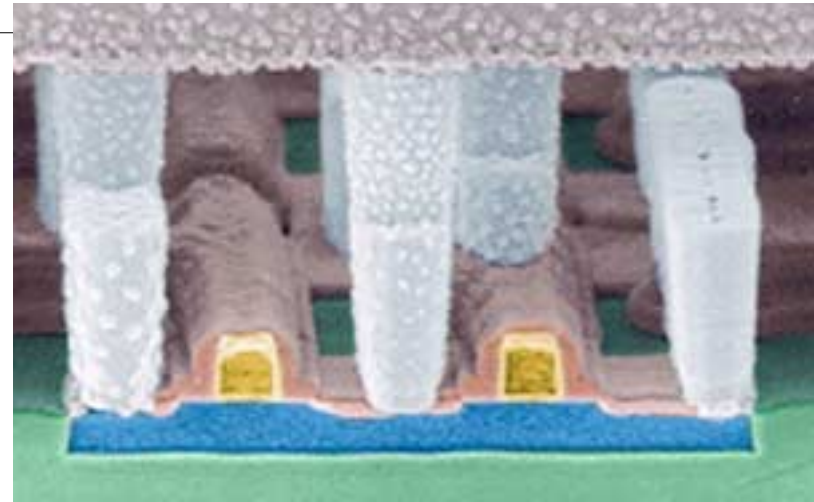
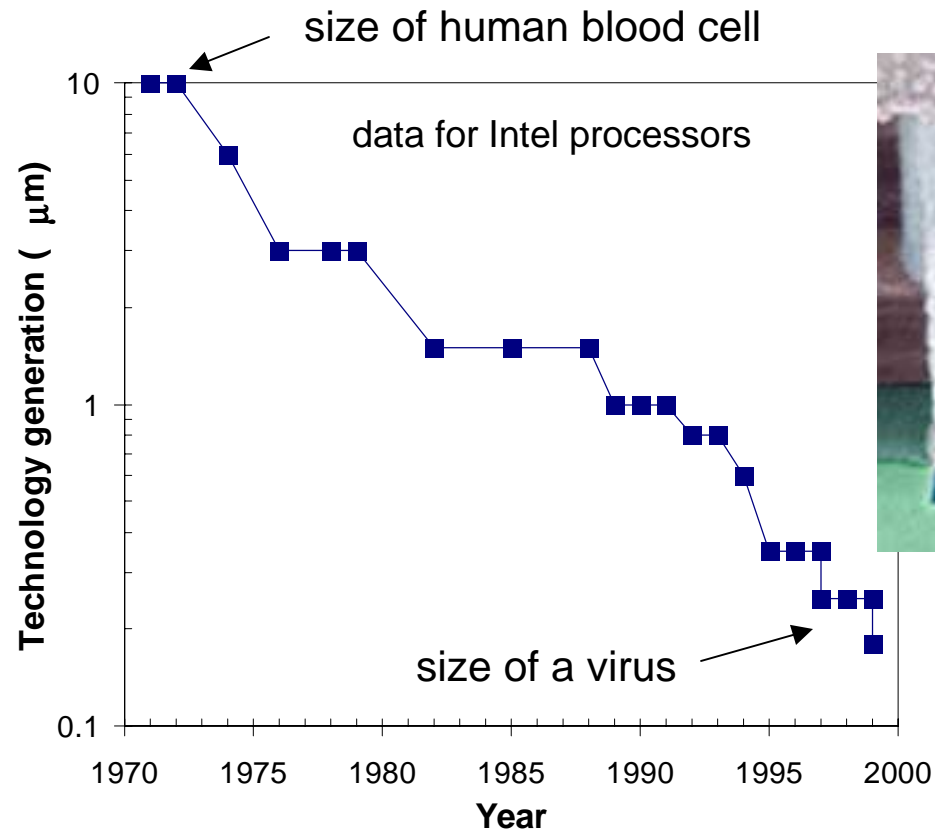
# Interconnects



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



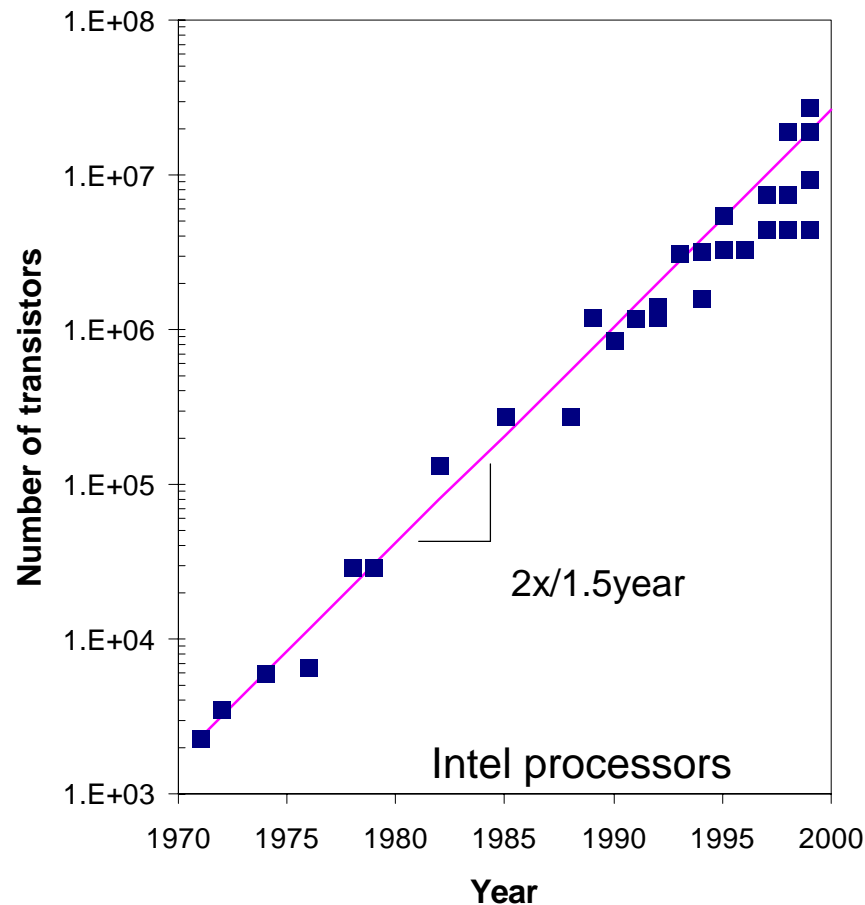
# Transistor size scaling



Rabies virus at same scale

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

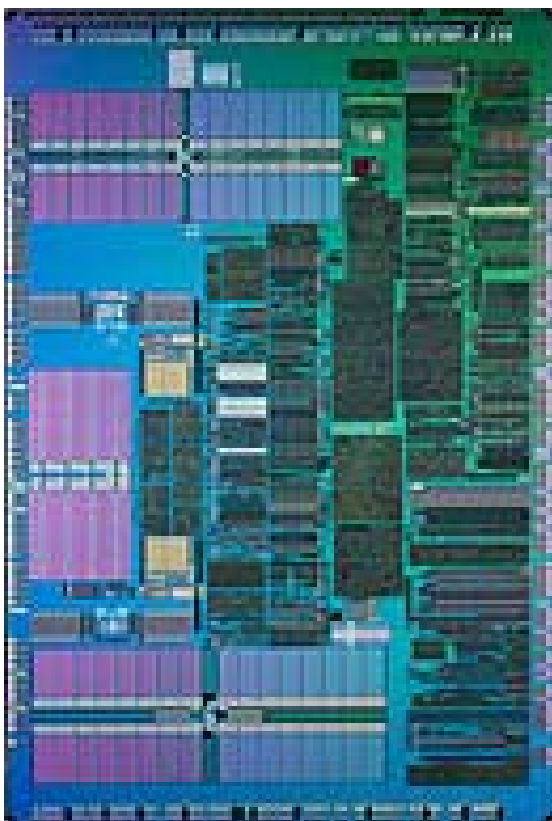
# Evolution of transistor density



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

4-orders of magnitude improvement in 30 years.

# Benefits of increasing transistor integration

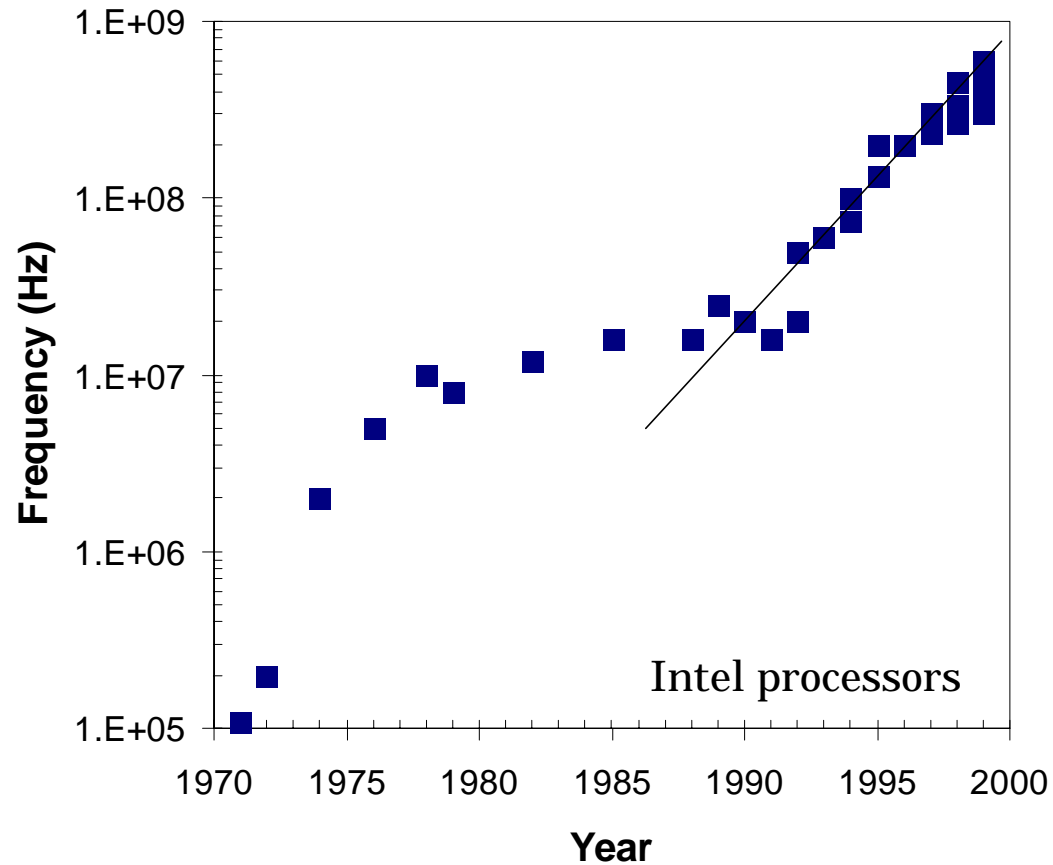


Exponential improvements in:

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

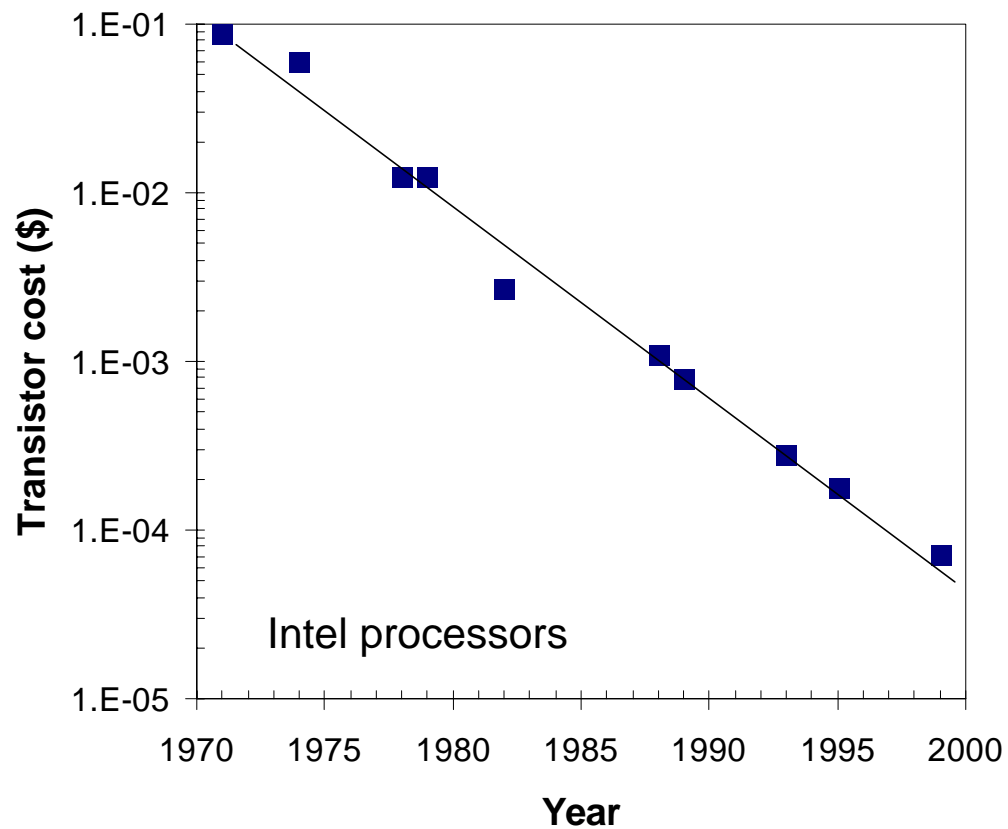
Experimental SOI microprocessor from IBM

# Clock speed



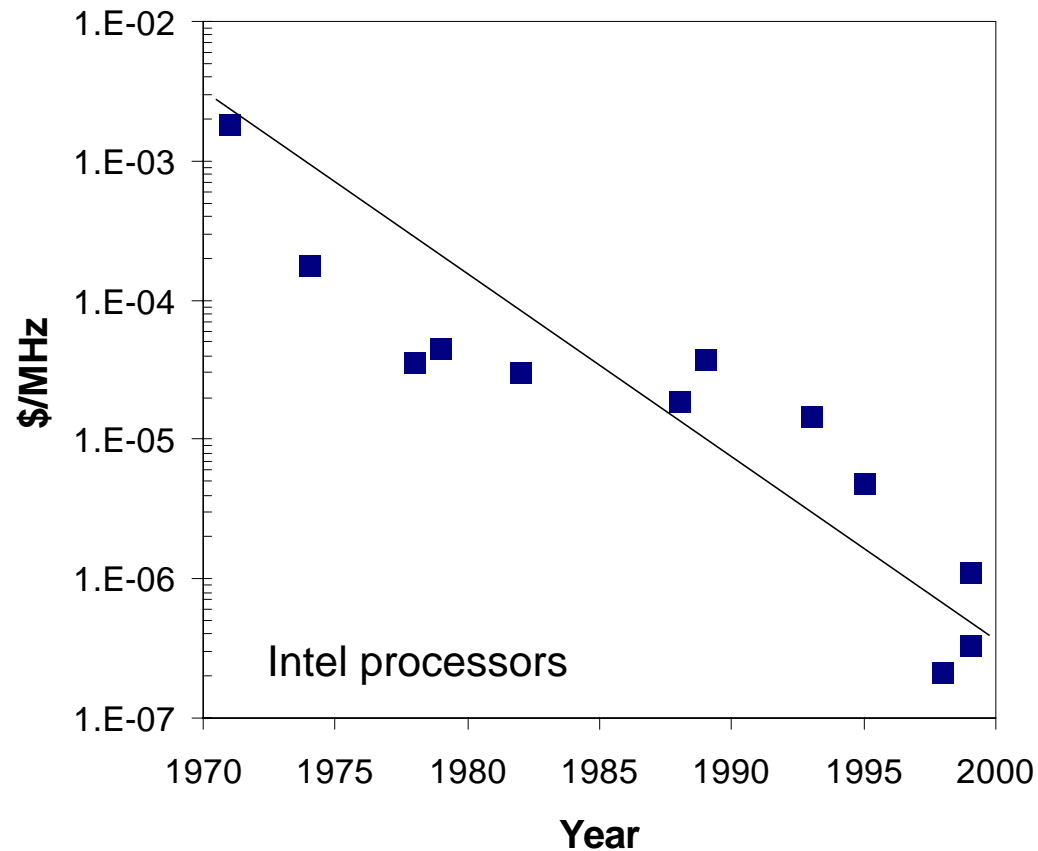
4-orders of magnitude improvement in 30 years.

# Transistor cost



3-order of  
magnitude reduction  
in 30 years.

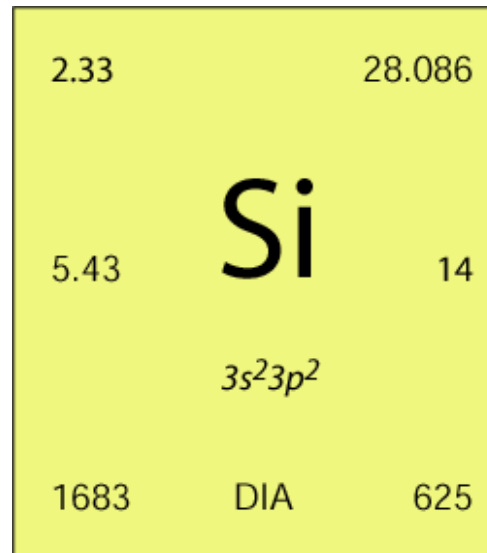
# Cost per function



4-order of  
magnitude  
reduction in 30  
years.

# Keys to success of digital microelectronics:

## I. Silicon



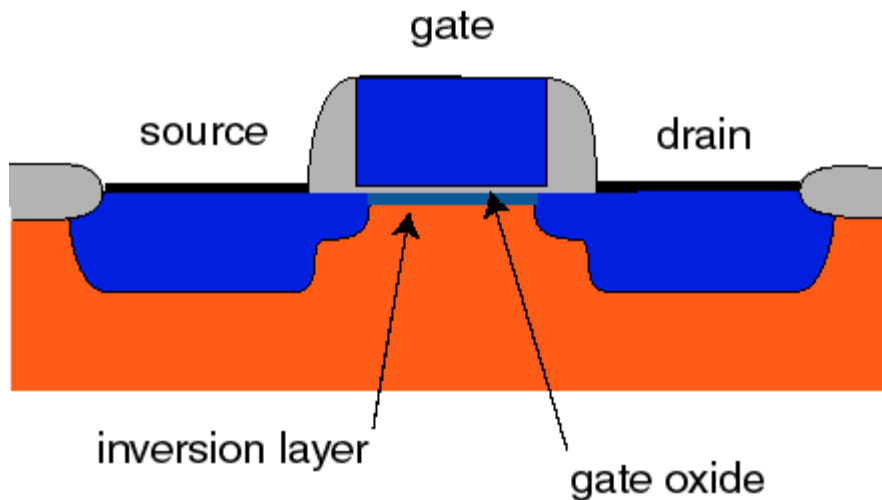
- Cheap and abundant
- Amazing mechanical, chemical and electronic properties
- Probably, the material best known to humankind

# Keys to success of digital microelectronics:

## II. MOSFET

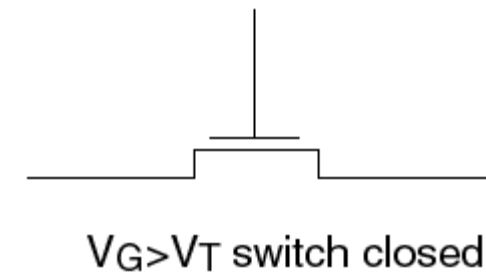
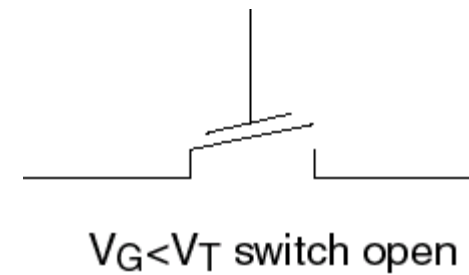
Metal-Oxide-Semiconductor

Field-Effect Transistor



Good gain, isolation, and speed

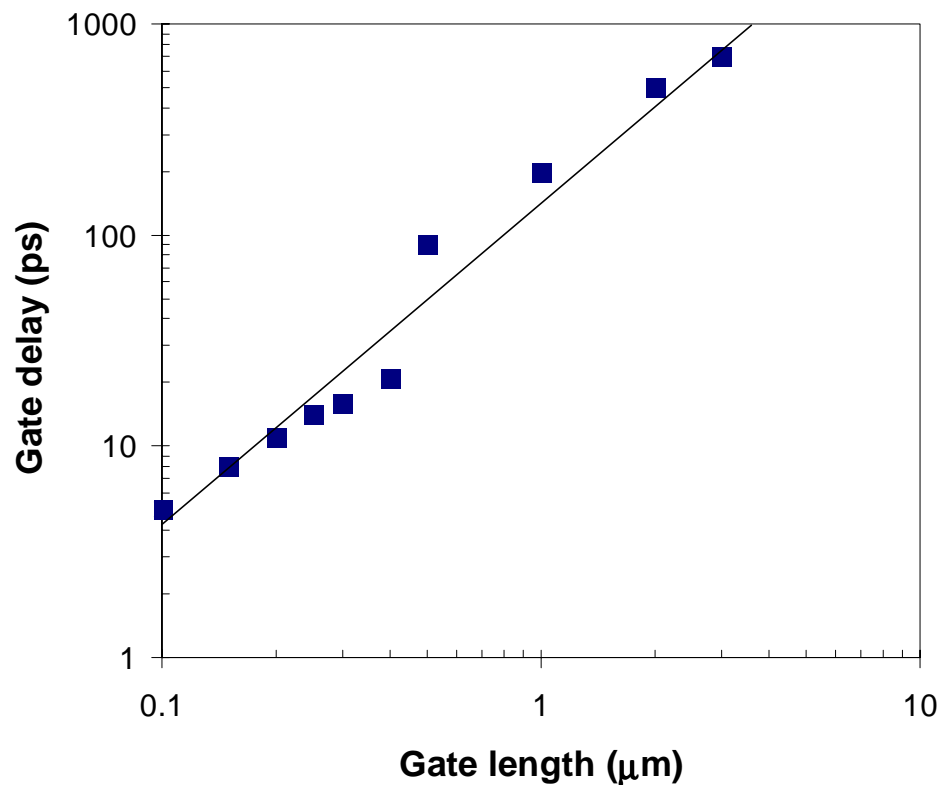
MOSFET = switch





# Keys to success of digital microelectronics:

## III. MOSFET scaling



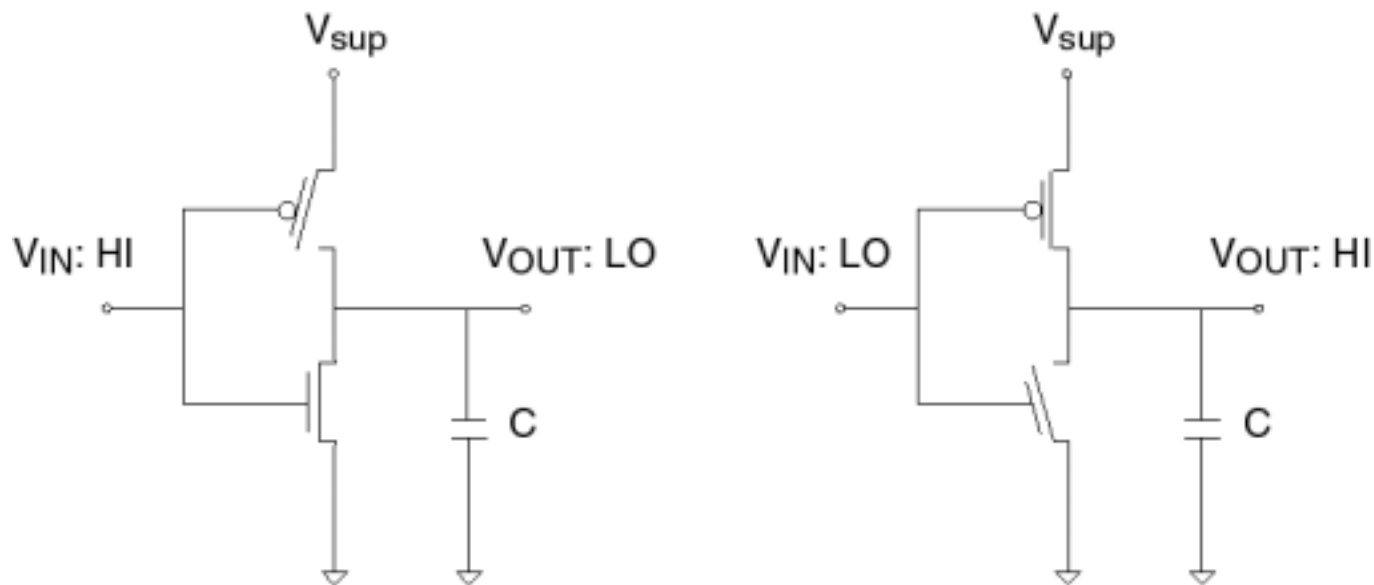
MOSFET performance improves as size is decreased:

- Shorter switching time
- Lower power consumption

# Keys to success of digital microelectronics:

## IV. CMOS

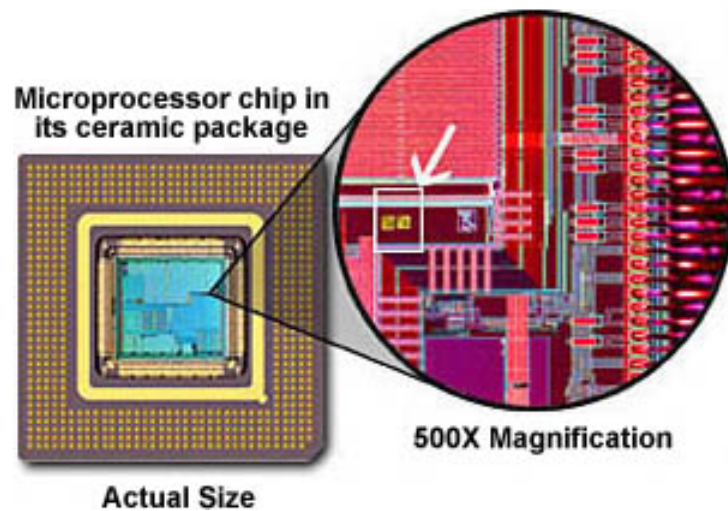
CMOS: Complementary Metal-Oxide-Semiconductor



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

# Keys to success of digital microelectronics:

## V. Microfabrication technology



Silicon Graphics MIPS R12000

- 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)

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

Wolfgang Pauli, 1931

*“To the electron –  
may it never be of any use to anybody.”*

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