6.720J/3.43J
Integrated Microelectronic Devices

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Fall 2002

Si microelectronics today

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

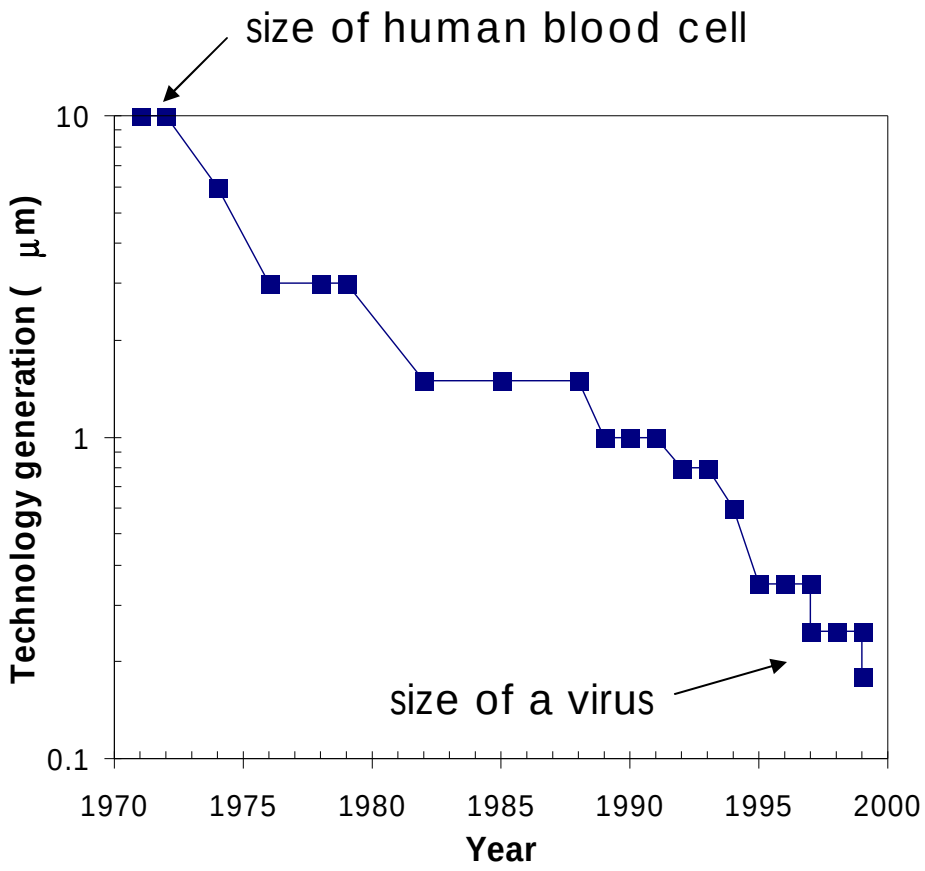
- A thick web of interconnects, many levels deep.
- High density of very small transistors.

Intel's Pentium IV

Interconnects

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

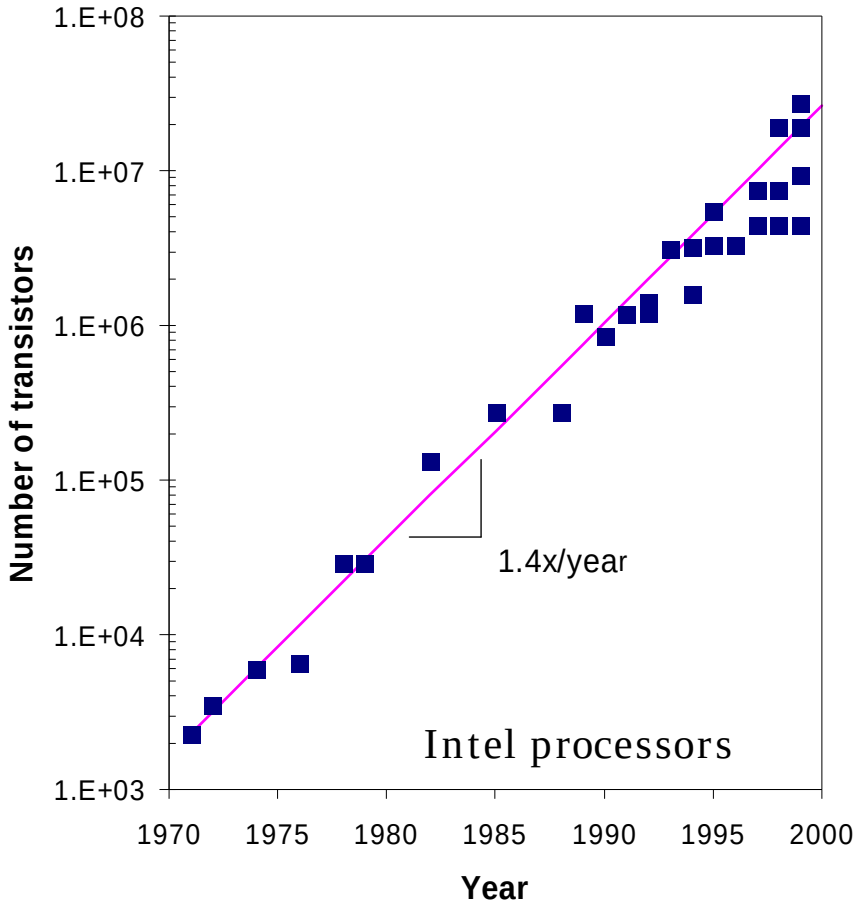
Transistor size scaling



data for Intel processors
picture from IBM

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!

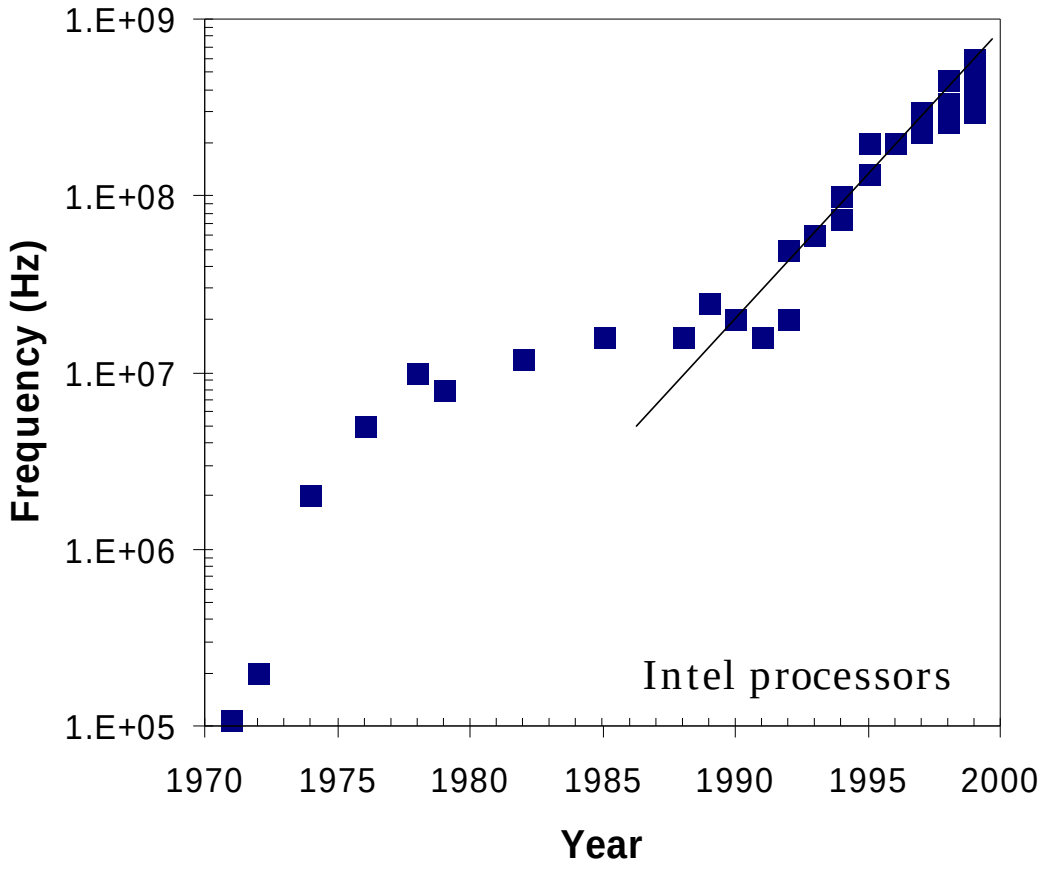
4-orders of magnitude improvement in 30 years.

Benefits of Si microelectronics revolution

Exponential improvements in:

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

Clock speed

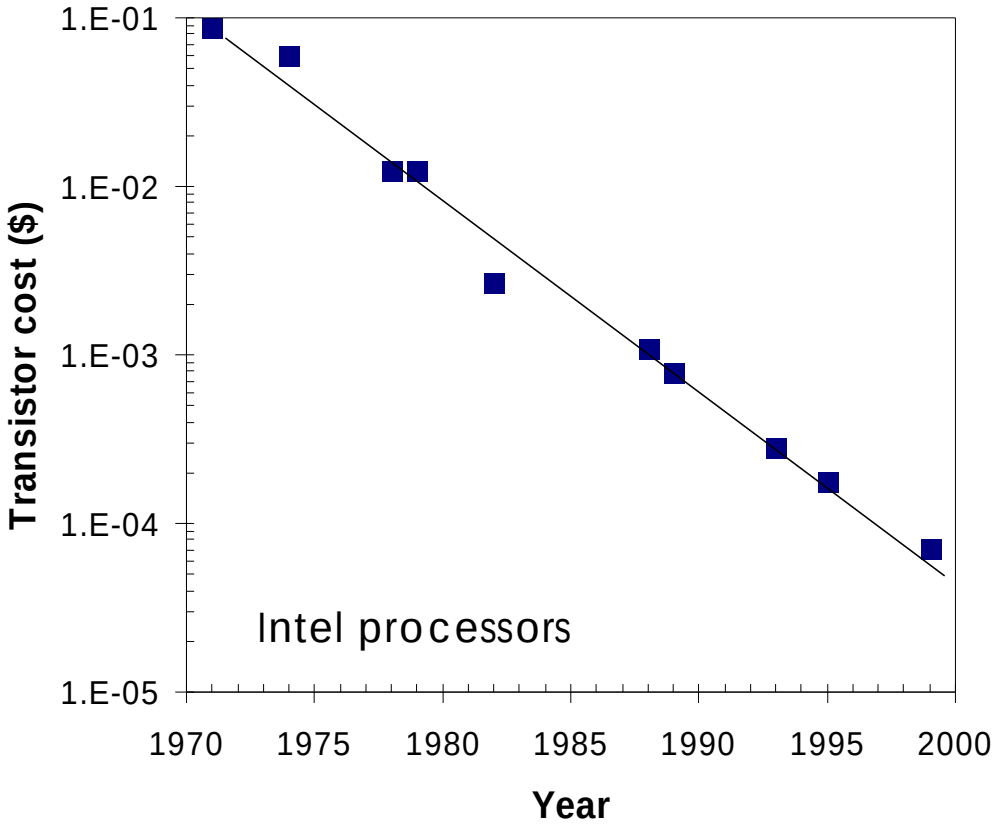


4-orders of magnitude improvement in 30 years.

Why?

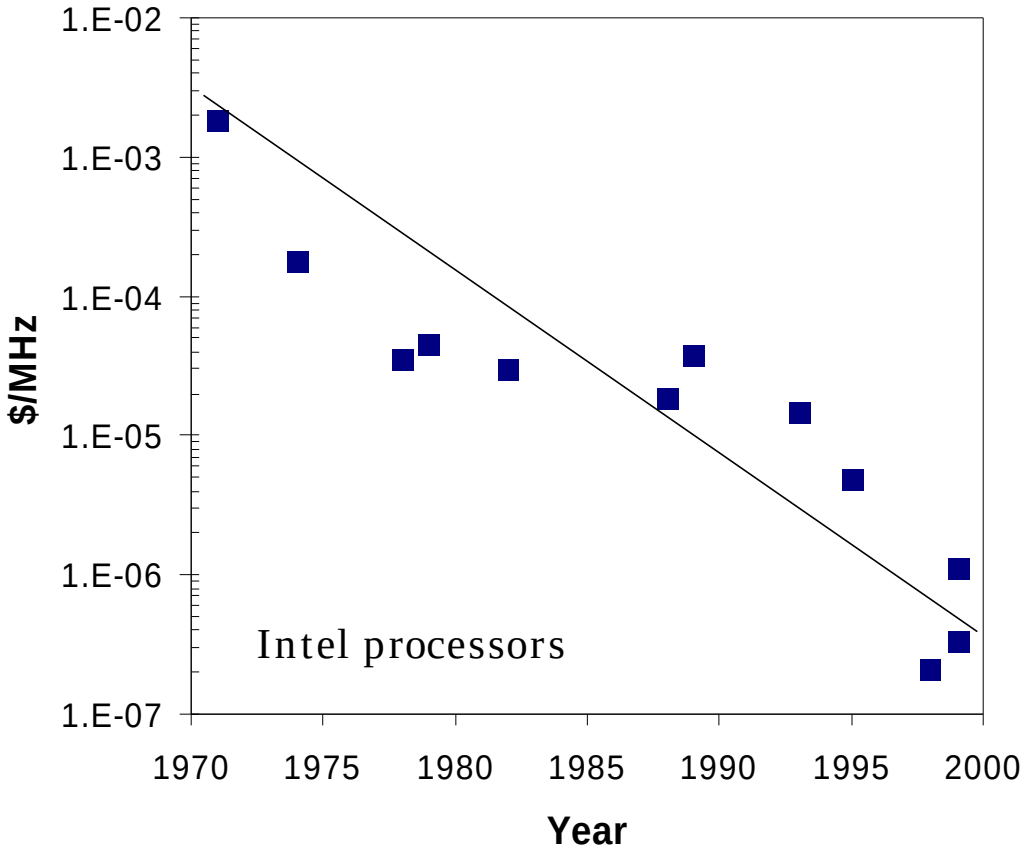
Answer in 6.720

Transistor cost



3-order of magnitude reduction in 30 years.

Cost per function

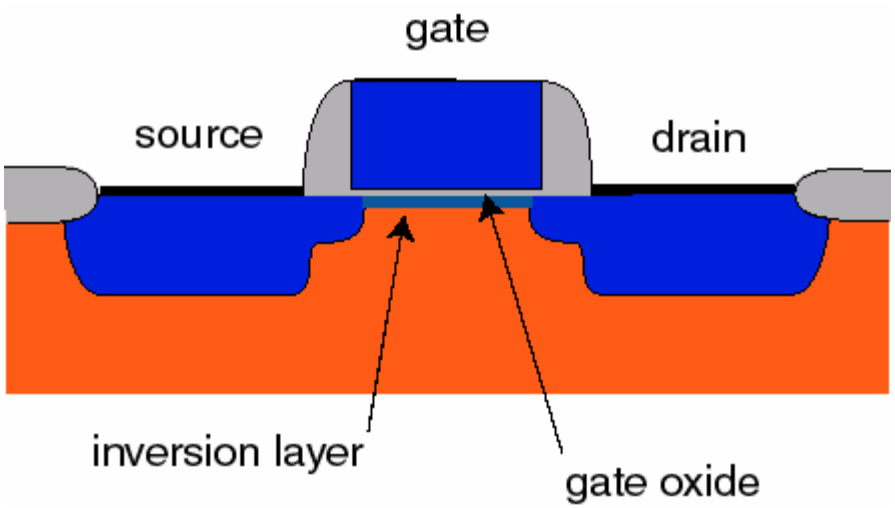


4-order of magnitude reduction in 30 years.

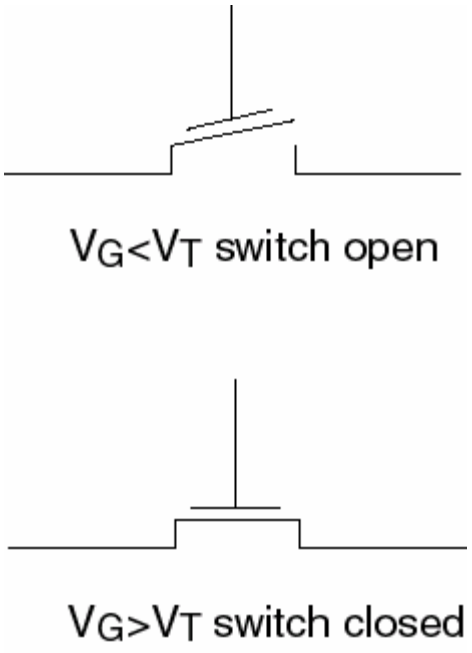
Keys to success: I. MOSFET

Metal-Oxide-Semiconductor

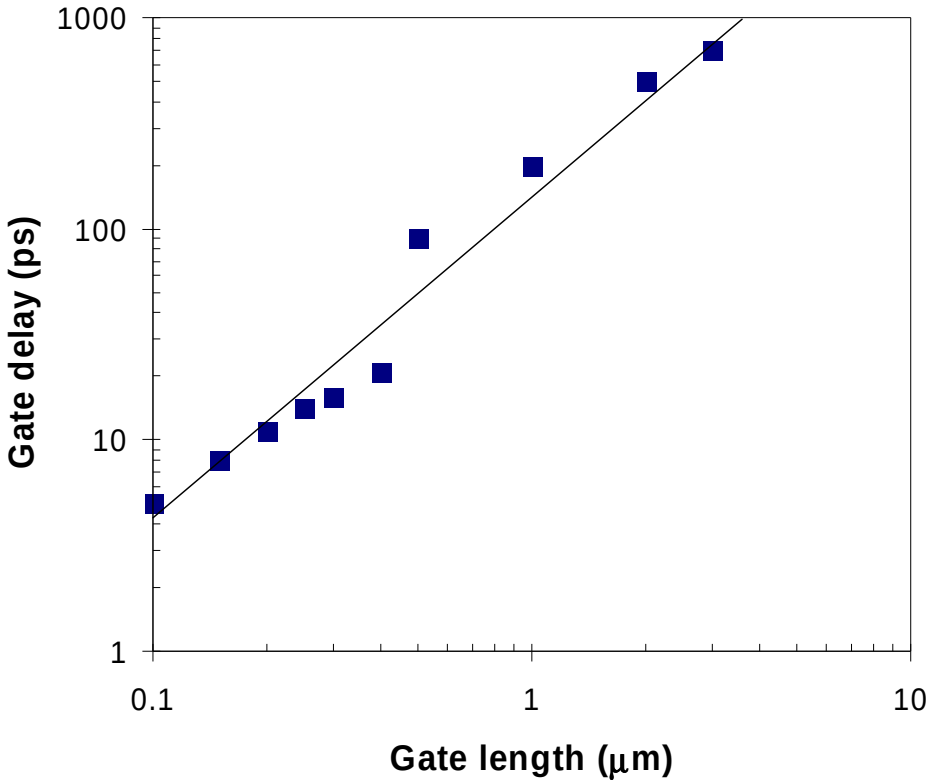
Field-Effect Transistor



MOSFET = switch



Keys to success: II. MOSFET scaling



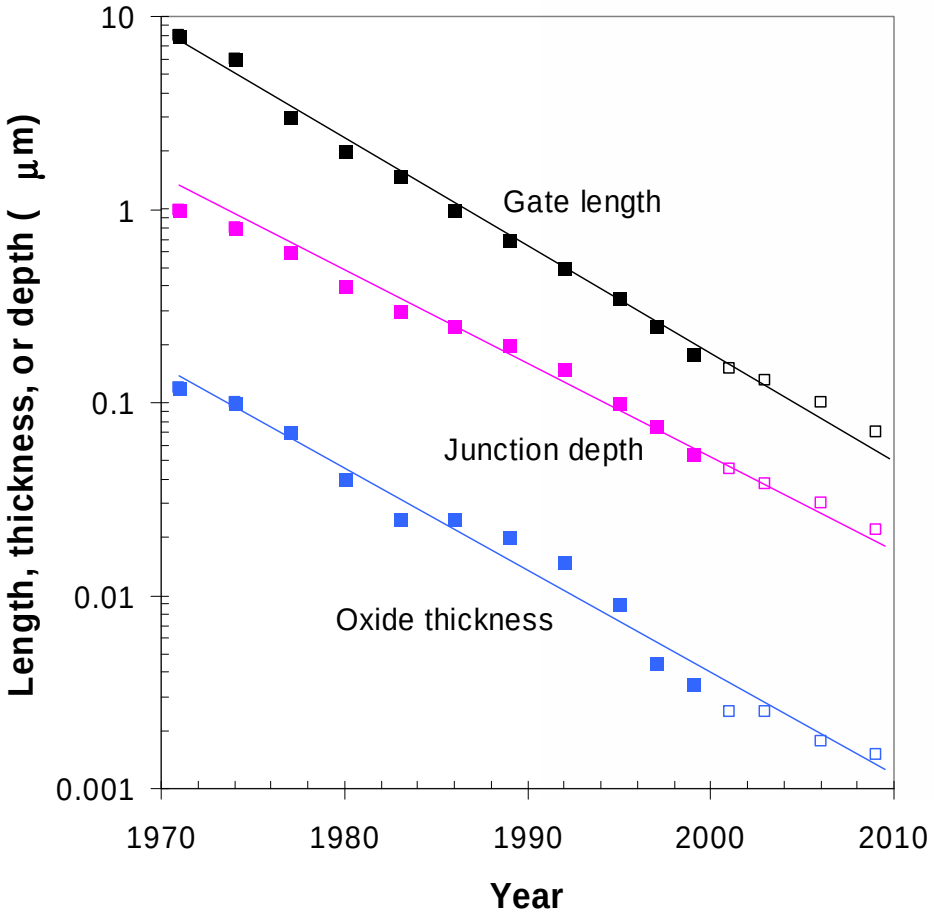
MOSFET performance improves as size is decreased:

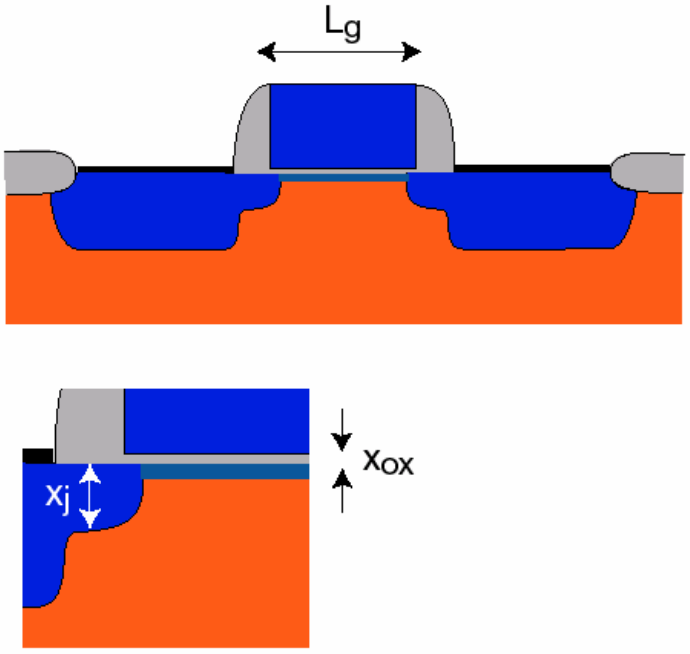
- Shorter switching time
- Lower power consumption

Why?

Answer in 6.720

Need “harmonious” scaling



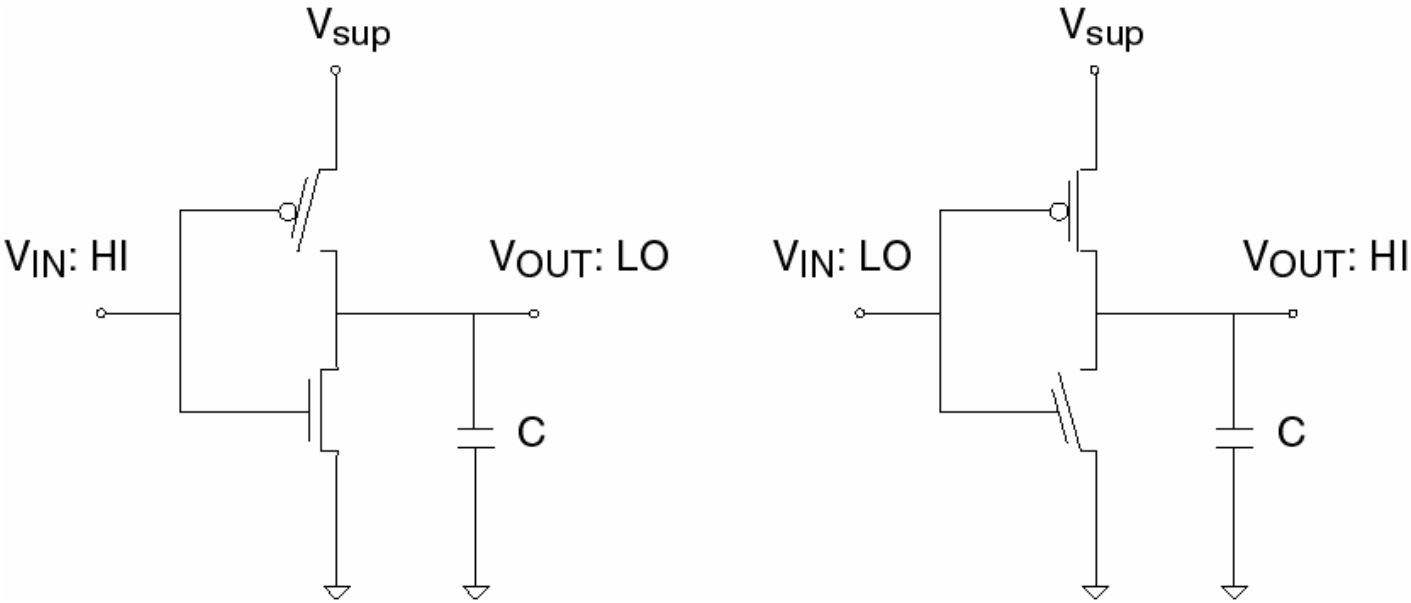


All dimensions scale in a balanced way to keep electrostatic integrity.

Why? Answer in 6.720

Keys to success: III. CMOS

CMOS: Complementary Metal-Oxide-Semiconductor



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

The New York Times (Oct. 9, 1999):

Chip Progress Forecast to Hit A Big Barrier

Scientists Seeing Limits to Miniaturization

Why?

Answer in 6.720

Objectives of 6.720J/3.43J

1. *Solid understanding of basic physical phenomena pervasive in microelectronic devices*:

- carrier transport (drift and diffusion)
- carrier generation and recombination
- carrier injection and extraction
- energy scale, time scale and length scale of key phenomena
- minority-vs. majority-carrier type devices
- pervasive non-ideal and parasitic effects
- energy band diagrams

Objectives of 6.720J/3.43J (cont.)

2. *Solid understanding (physics and modeling) of main-stream integrated microelectronic devices*:

- Schottky diode
- p-n diode
- **MOSFET**
- BJT

3. *Appreciation of major trends in microelectronics industry*.

Boundaries of 6.720J/3.43J

- Almost no light => no optical devices
- No heterostructures => no HBT or MODFET
- No *E-K* diagrams => need to "fudge" physical description at times
- No device applications => discuss only device-level figures of merit

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

Wolfgang Pauli, 1931