IC Technology

What advantages do ICs have over discrete components?

- *Size:* Sub-micron vs. millimeter/centimeter.

- *Speed and Power:* Smaller size of IC components yields **higher speed** and **lower power** consumption due to smaller parasitic resistances, capacitances and inductances.

  Switching between '0' and '1' much faster on chip than between chips.

  Payoff at the system level:

  Systems are physically smaller, e.g. cell phones.

  Lower power consumption ripple effect => less heat => cheaper power supplies => reduced system cost.

- Integrated circuit manufacturing is **versatile.**

  Simply change the mask to change the design.

  However, designing the layout (changing the masks) is usually the most time consuming task in IC design.

IC Technology

A Sample of Integrated Circuit technologies:

MOS

- CMOS
- PMOS-only
- NMOS-only

Bipolar

- Transistor-transistor logic (TTL)
- Integrated Injection Logic (I^2L)

Gallium Arsenide (GaAs)

Silicon Germanium

BiCMOS

Superconducting technologies

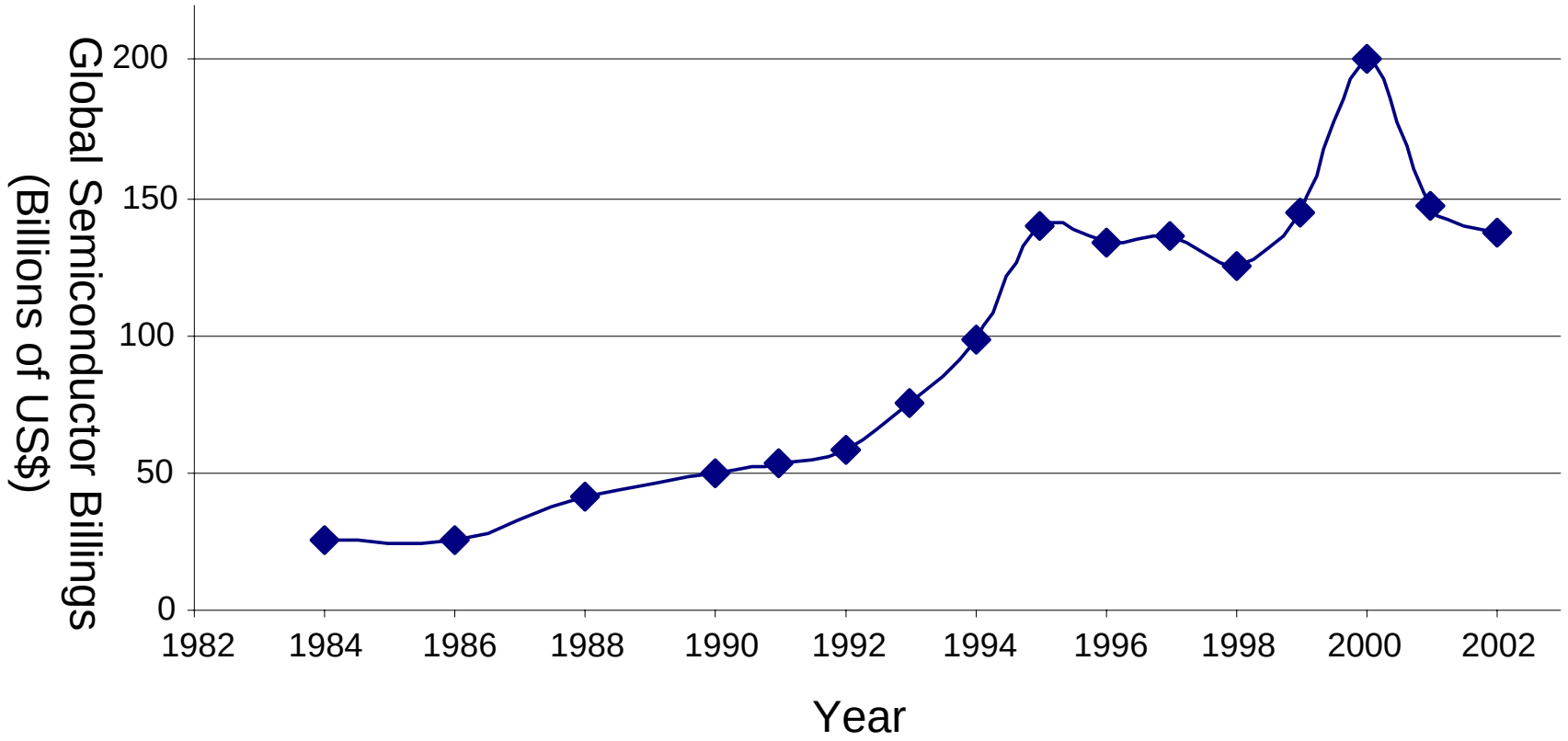
Brief History

- 1958: First Integrated Circuit
  - Flip-flop using two transistors
  - Built by Jack Kilby at Texas Instruments
- 2004
  - Intel Pentium 4 microprocessor (~55 million transistors)
  - 512 Mbit DRAM (> 0.5 billion transistors)
- 53% compound annual growth rate over 45 years
  - No other technology has grown so fast so long
- Driven by miniaturization of transistors
  - Smaller is faster, cheaper, lower in power
  - Revolutionary effects on society
- Feature Size: Smallest feature on an IC, currently the length of the transistor
  - Current feature sizes: 130 nm/ 90 nm

Annual Sales

10^{18} transistors manufacture in 2003

100 million for every human on the planet



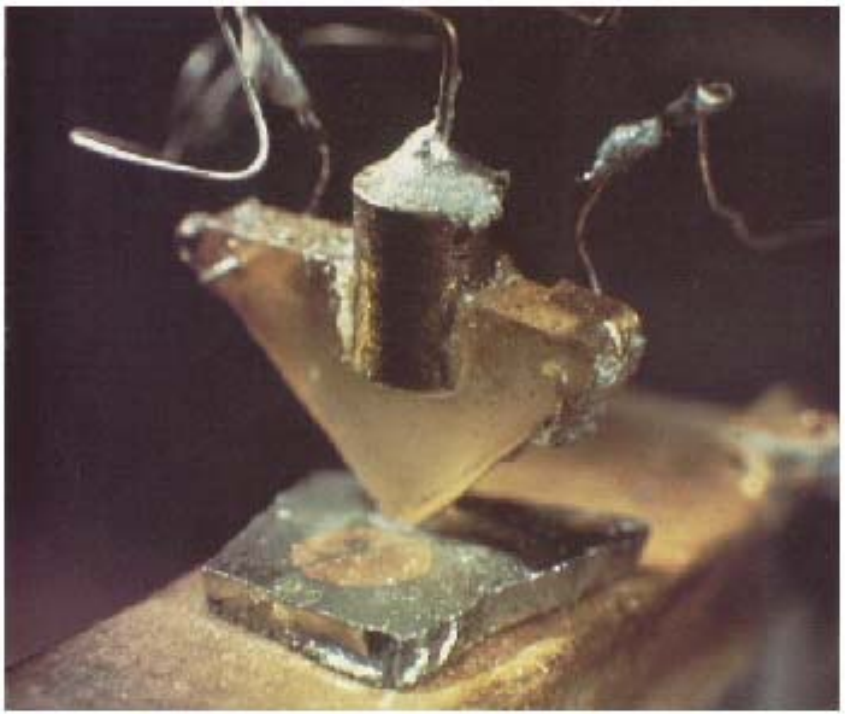
Invention of the transistor

Vaccum-tubes ruled in the first half of 20th century.

Large, expensive, power-hungry, unreliable

1947: First point contact transistor

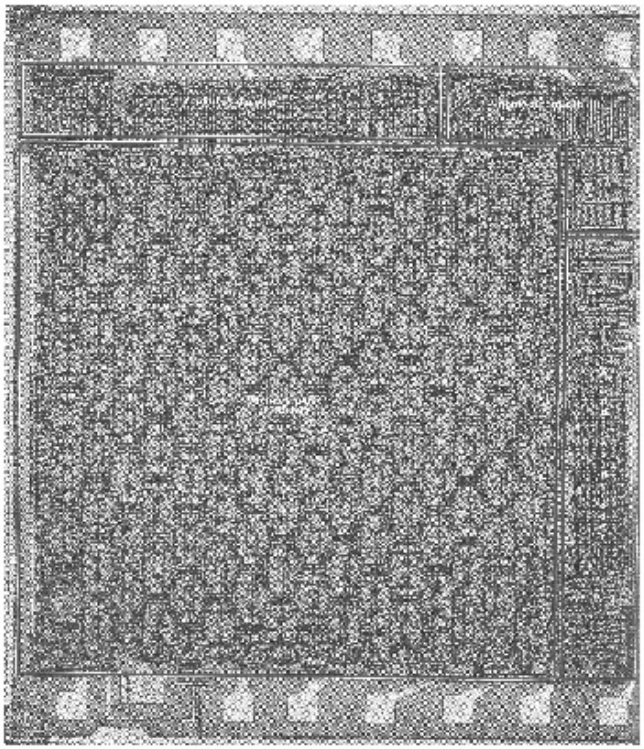
John Bardeen and Walter Brattain at Bell Labs



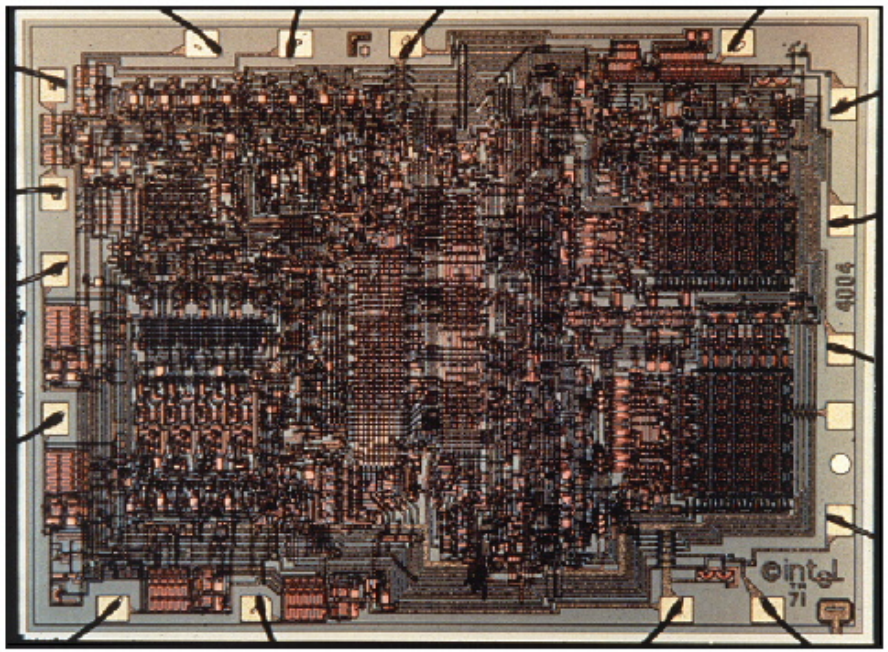
MOS Integrated Circuits

1970′s processes usually had only nMOS transistors

Inexpensive, but consume power when idle



Intel 1101 256-bit SRAM



Intel 4004 4-bit μProcessor

1980′s present: CMOS processes for low idle power

Why CMOS?

Power consumption (heat) of bipolar circuits reduce level of integration.

- Multiple ICs offset advantage of faster speed of bipolar since intra-chip signal propagation is much smaller than inter-chip propagation.
- On-chip wires suffer capacitance and resistance. However, off-chip wires suffer from capacitance and inductance (ringing effects).

CMOS advantages:

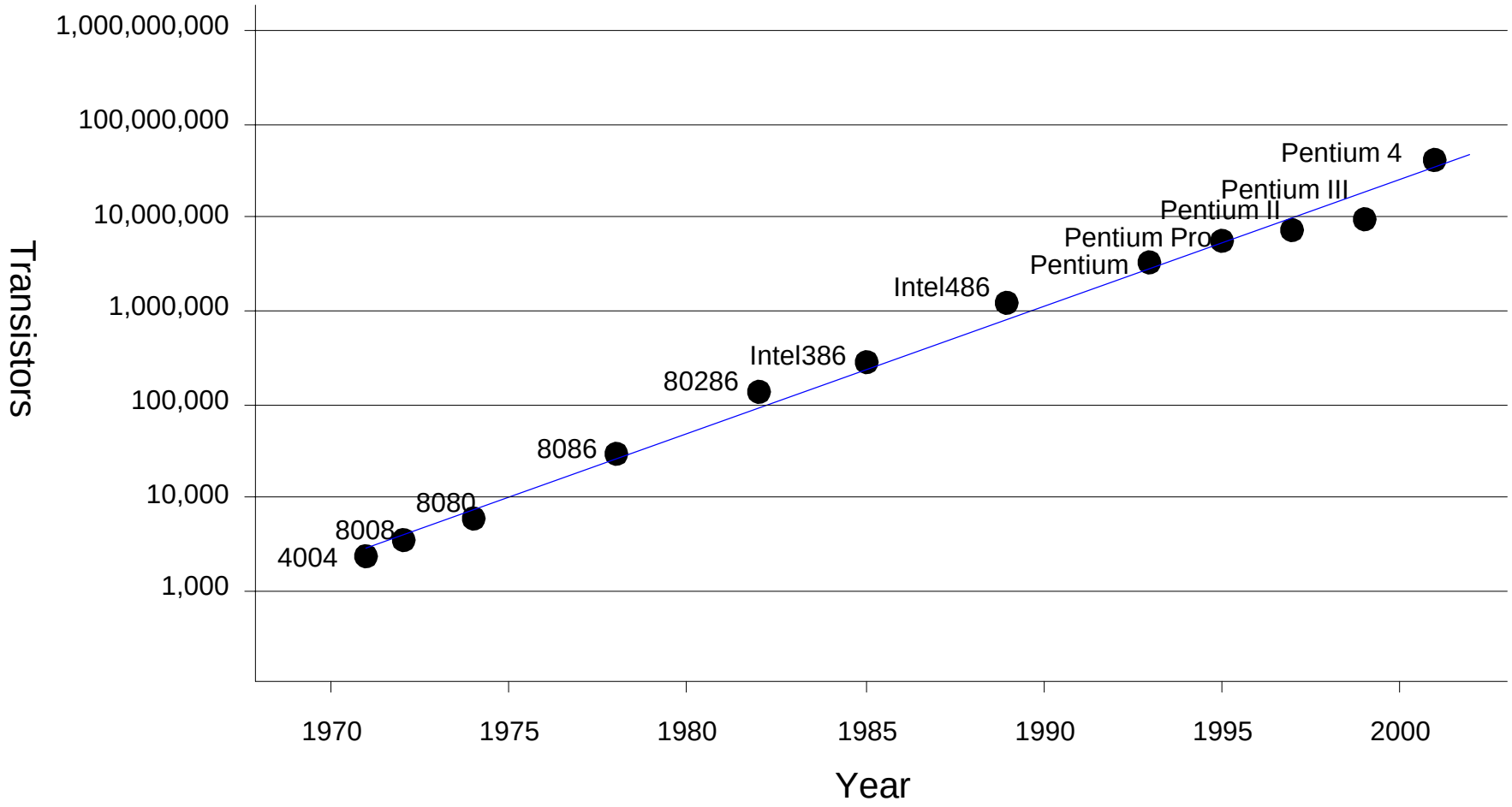
- Low power.
- Fully restored logic levels.
- Rise and fall transition times are of the same order.
- Very high levels of integration.
- High performance.

Moore's Law

1965: Gordan Moore plotted transistor on each chip

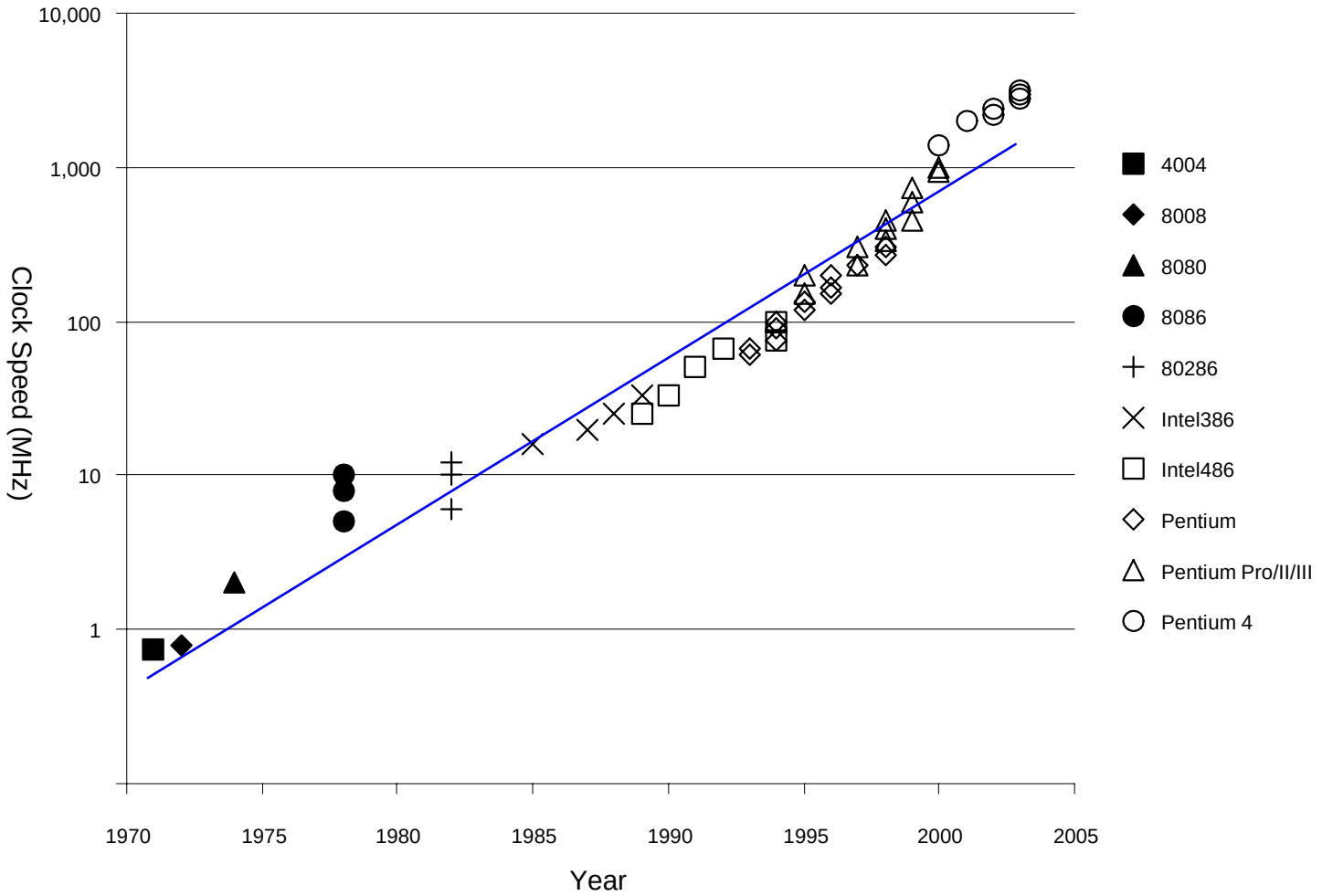
Fits straight line on a semilog plot

Transistor count doubles every 18-26 months



Corollaries

Many other factors grow exponentially (clock frequency, processor performance, ...)



Cost of building a semiconductor fab is doubling every three to four years.