

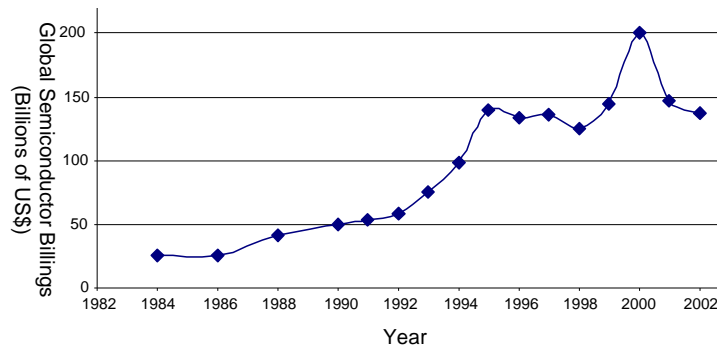
Moore's Law

A Brief History

- 1958: First integrated circuit
 - Flip-flop using two transistors
 - Built by Jack Kilby at Texas Instruments
- 2003
 - Intel Pentium 4 μ processor (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 cheaper, faster, lower in power!
 - Revolutionary effects on society

Annual Sales

- 10^{18} transistors manufactured in 2003
 - 100 million for every human on the planet

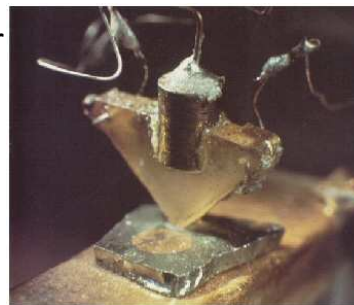


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Invention of the Transistor

- Vacuum tubes ruled in first half of 20th century
 - Large, expensive, power-hungry, unreliable
- 1947: first point contact transistor
 - John Bardeen and Walter Brattain
 - Read *Crystal Fire* by Riordan, Hodgeson



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Transistor Types

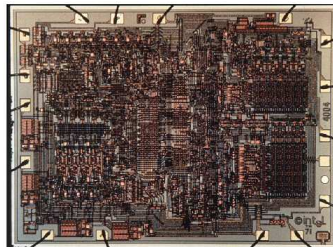
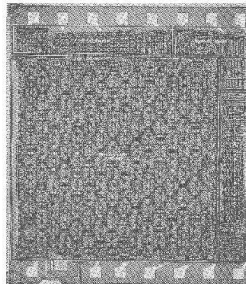
- **Bipolar transistors**
 - npn or pnp silicon structure
 - Small current into very thin base layer controls large currents between emitter and collector
 - Base currents limit integration density
- **Metal Oxide Semiconductor Field Effect Transistors**
 - nMOS and pMOS MOSFETS
 - Voltage applied to insulated gate controls current between source and drain
 - Low power allows very high integration

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MOS Integrated Circuits

- 1970's processes usually had only nMOS transistors
 - Inexpensive, but consume power while idle



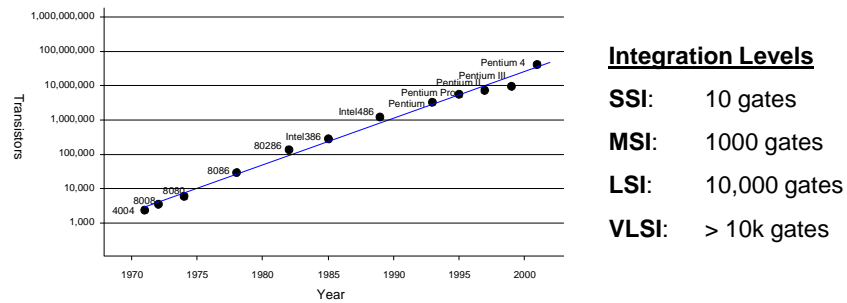
- Intel 1101 256-bit SRAM
- Intel 4004 4-bit uProc
- 1980s-present: CMOS processes for low idle power

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Moore's Law

- 1965: Gordon Moore plotted transistor on each chip
 - Fit straight line on semilog scale
 - Transistor counts have doubled every 26 months

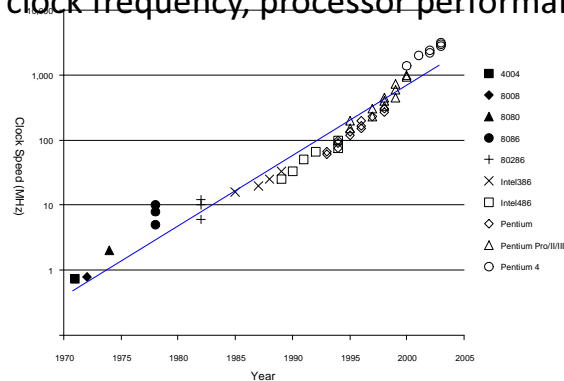


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Corollaries

- Many other factors grow exponentially
 - Ex: clock frequency, processor performance



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