Lecture 1
6.012 Introduction

Outline

1. Overview of 6.012
2. Key conclusions of 6.012

Reading Assignment: Howe and Sodini, Chapter 1

Overview of 6.012

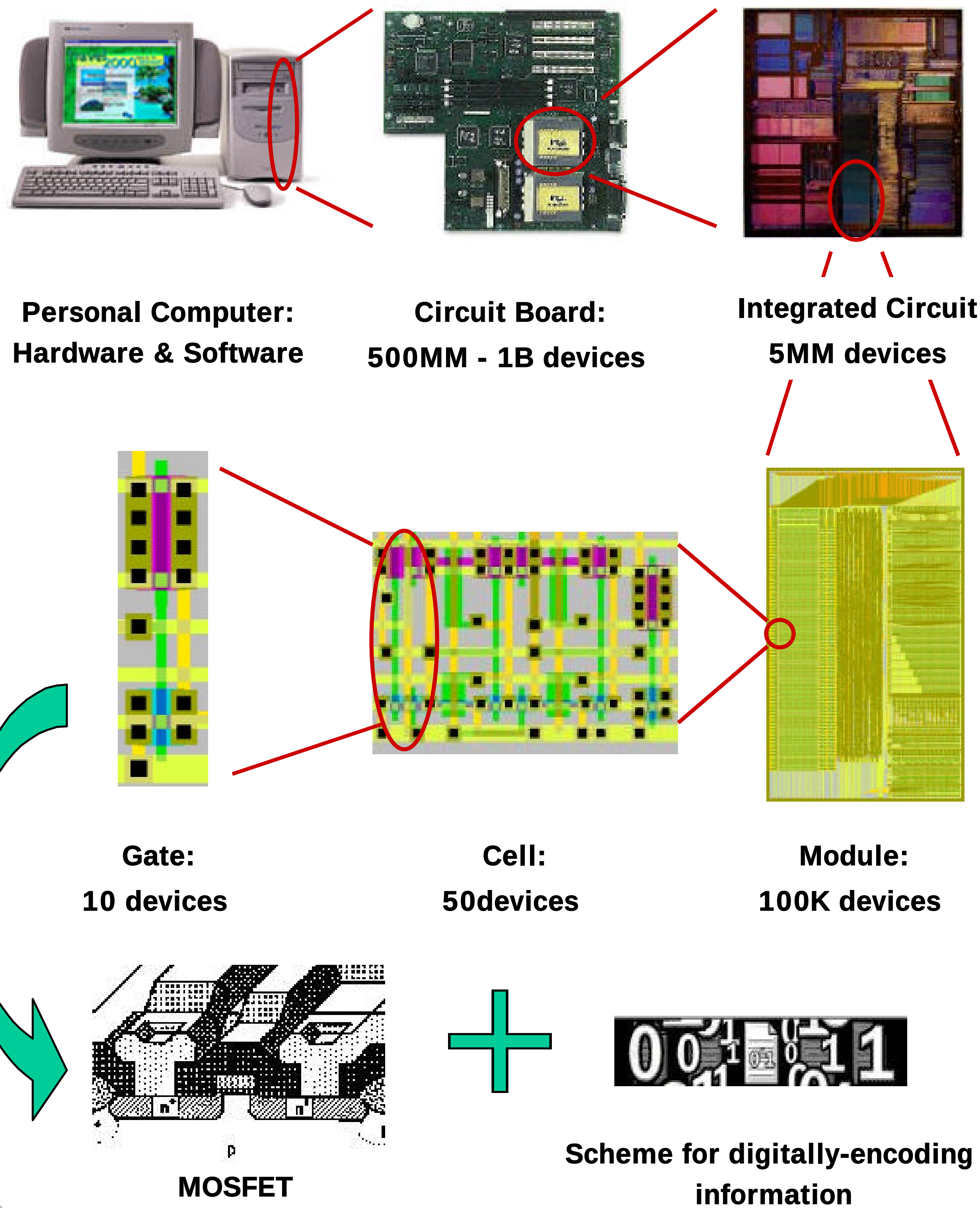
6.012: Introductory subject to *microelectronic* devices and circuits

- MICROELECTRONIC DEVICES
  - Semiconductor physics
  - Metal-oxide-semiconductor field-effect transistors (MOSFETs)
  - Bipolar junction transistors (BJTs)
- MICROELECTRONIC CIRCUITS
  - Digital circuits (mainly CMOS)
  - Analog circuits (BJT and CMOS)

Applications of Semiconductors

- Logic Circuits
  - Computers, Digital Signal Processors
- Amplifiers
  - Hi-Fi, Wireless & μWave Communication, Telephony
- Memories
  - DRAM, SRAM, NVRAM
- Lasers
  - Optical Fiber Communication, CD Players
- Photodiodes
  - Receivers for Optical Communication, Digital Camera
- Charge Coupled Device (CCD)
  - Digital Camera
- Many others
  - Sensors, Actuators, MEMS

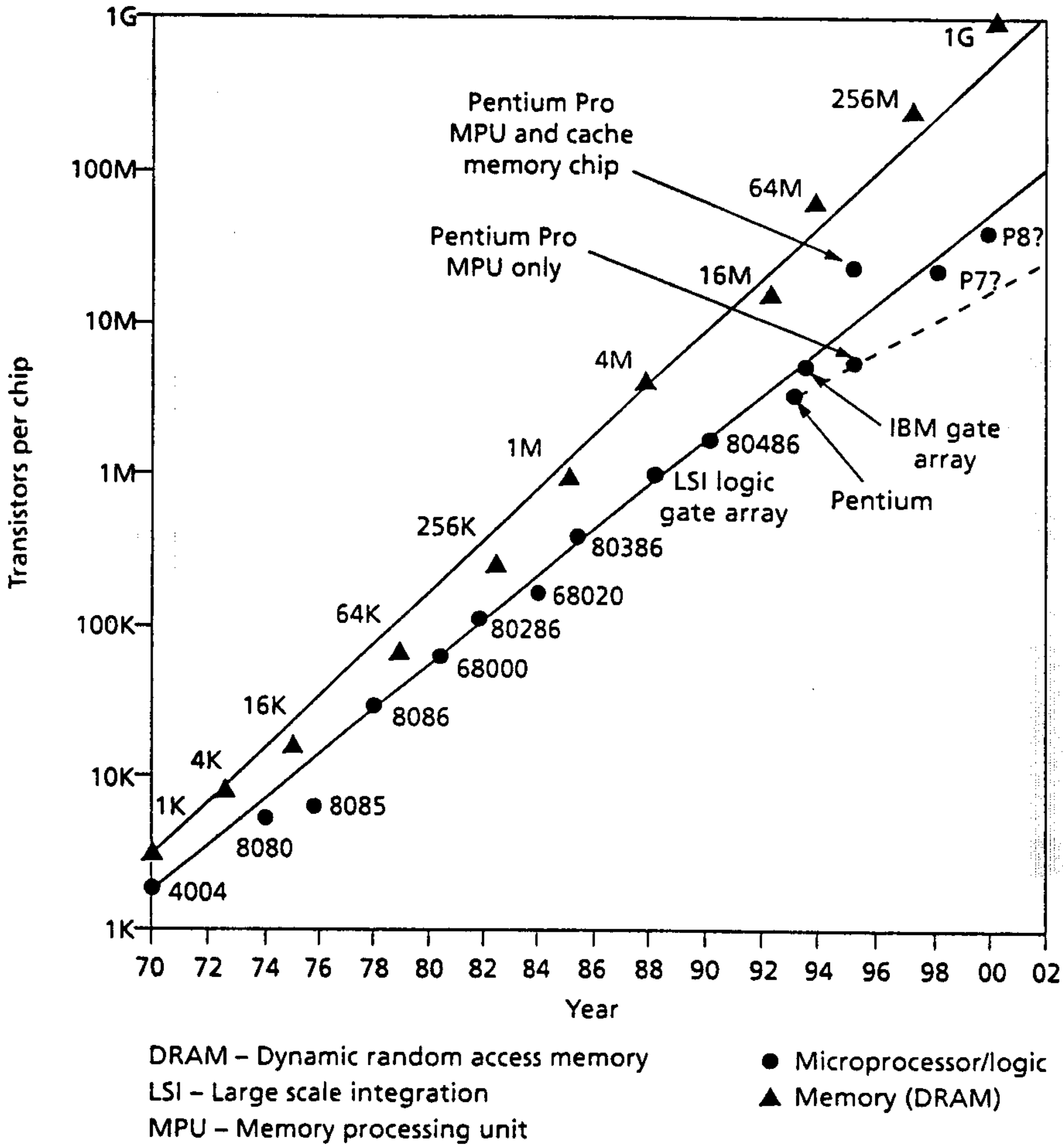
Let's look inside a system...



Microelectronic devices and circuits- cornerstones of electronic revolution

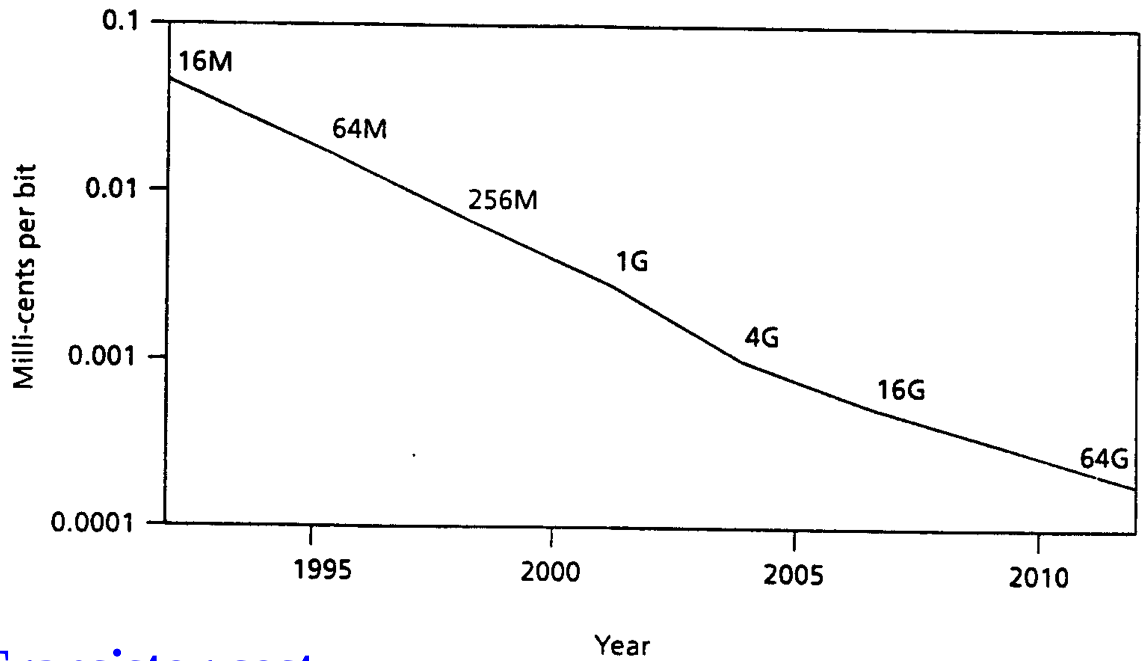
- Exponential growth in complexity and functionality of integrated circuits [Moore's law]
- Exponential decrease in power per function and cost per function of integrated circuits
- Profound penetration of IC technology into all aspects of human society

DRAM and Microprocessor Roadmap

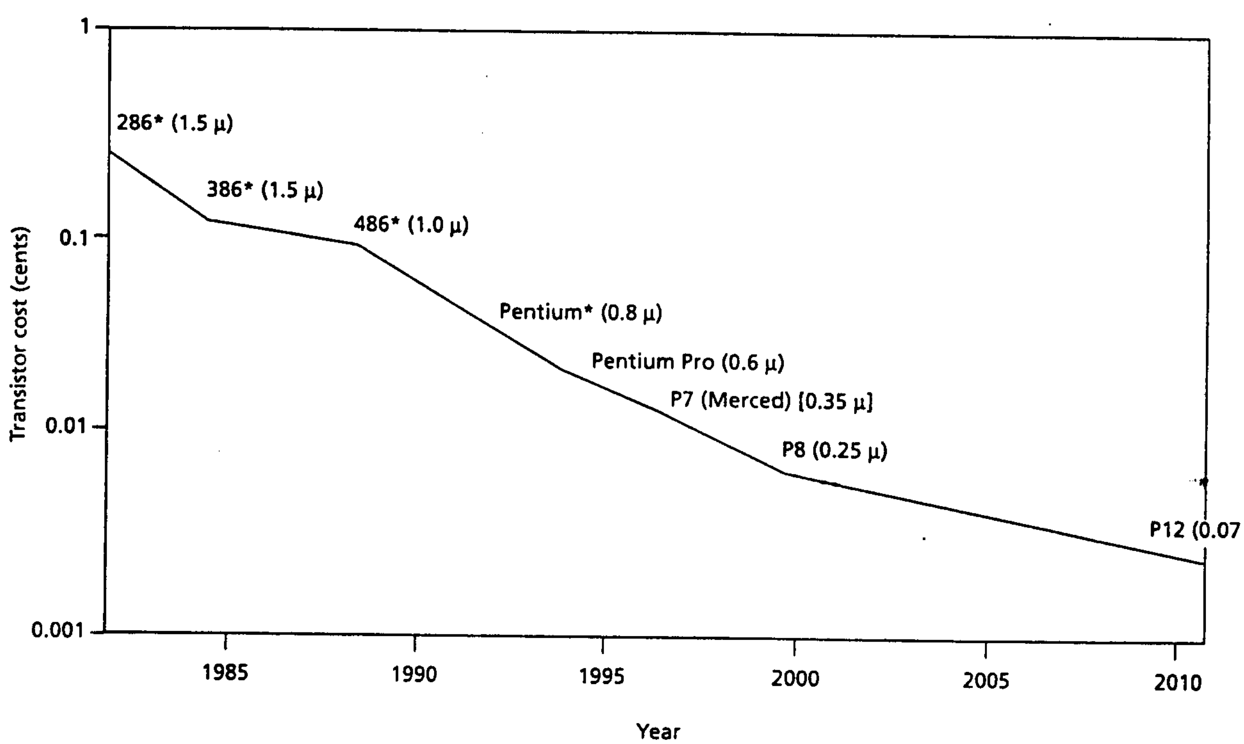


Cost Reduction of Electronics

Memory cost per bit



Transistor cost



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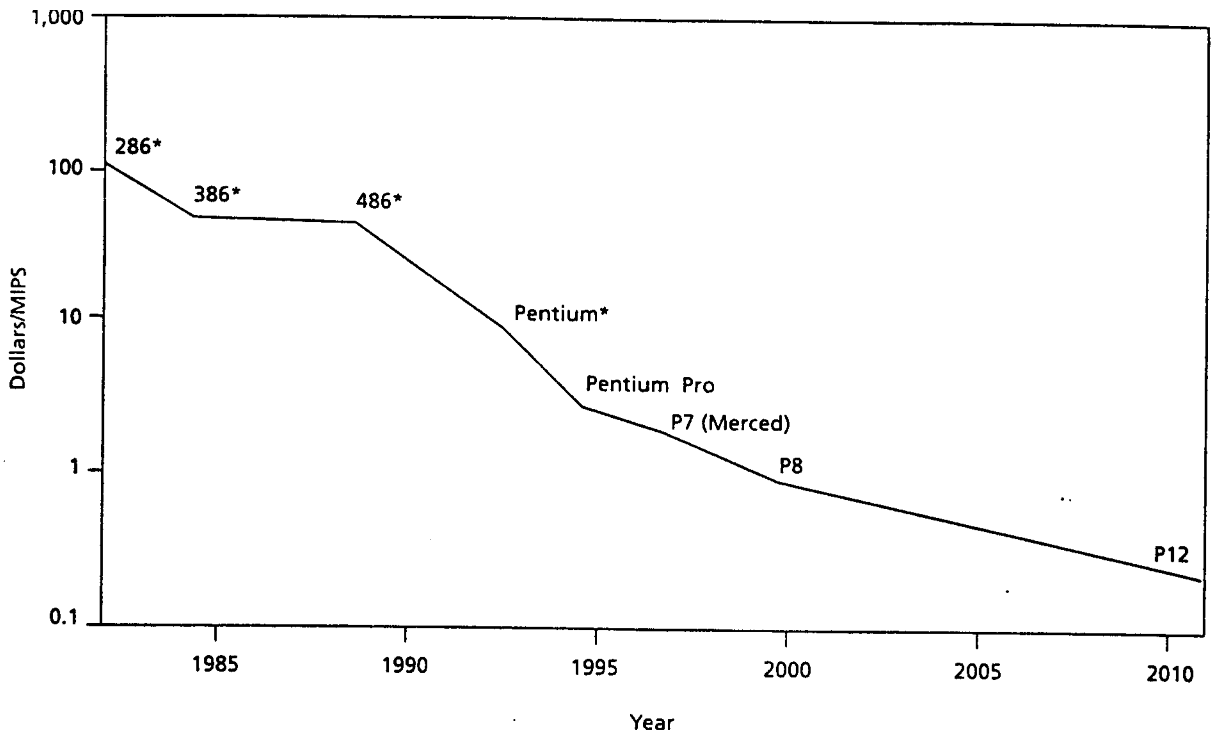
Reduction in Cost of Computation



MIPS – Millions of instructions per second

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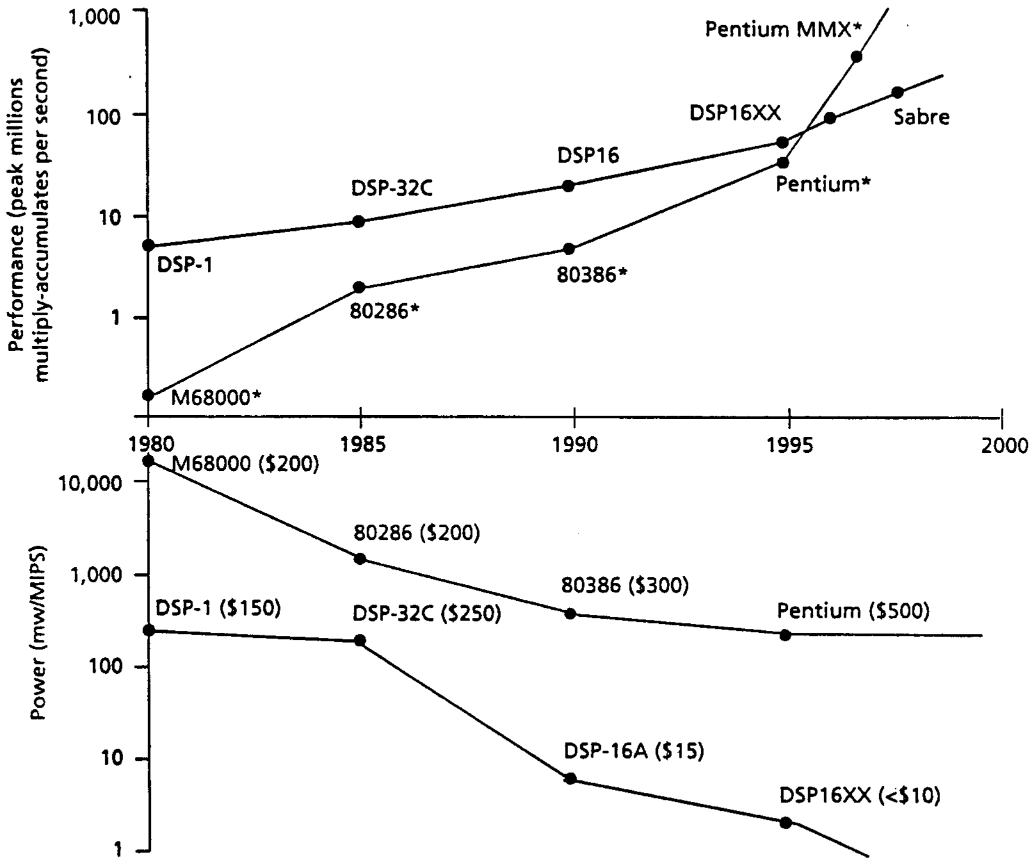
Cost and Performance of DSPs



DSP – Digital signal processor
MIPS – Millions of instructions per second

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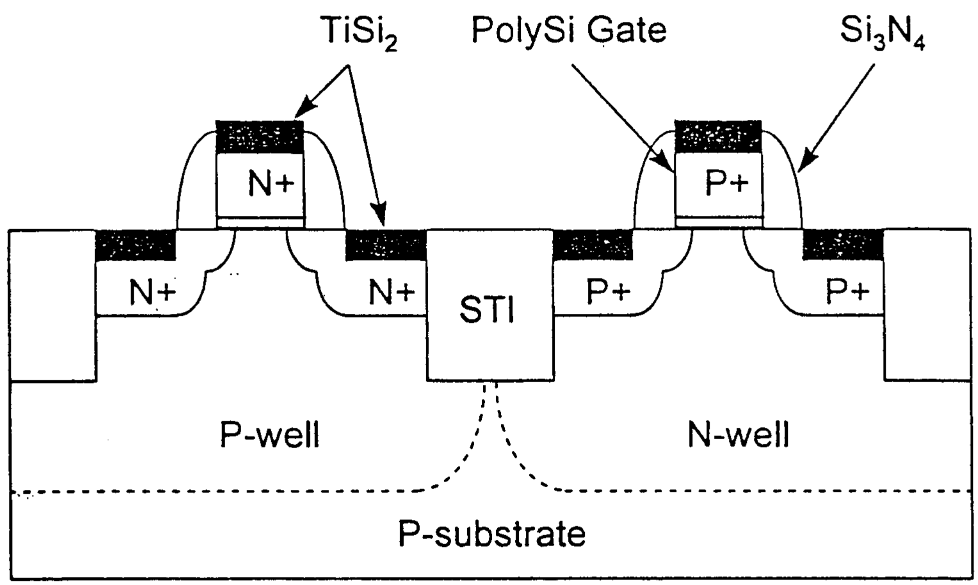
2. Key Conclusions from 6.012

Electronics revolution enabled by:

- *Semiconductor Si* and its amazing mechanical, chemical and electronic properties [probably the best material known to humankind]
- *MOSFET*
  - Device with good gain, isolation and speed
  - Comes in two "complementary" flavors
  - Scales well in size
- *Microfabrication Technology*
  - Batch fabrication of electronic circuits allows the manufacturing of an entire circuit, say 10^6 transistors and associated wiring on a single single crystal Si chip
  - Fabrication of extremely small structures, precisely and reproducibly
  - Tight integration of dissimilar devices with good isolation
  - High-volume manufacturing of complex systems with high yield

NMOS and PMOS transistors



Vanishingly Small IC

Panel 4. The Vanishingly Small

In the last thirty years, the typical feature size of an integrated circuit (IC) has shrunk dramatically, as shown in **Figure 2**. The success of the experimental arrangement of Shockley, Brattain, and Bardeen depended on dimensions of about 75 µm. Today's typical IC contains features of about 0.30 µm, almost 250 times smaller than the dimensions of the original Bell Labs apparatus. Researchers now believe that the ultimate dimensional limit of ICs will be about 0.05 µm, down another factor of 6 from where ICs are today. Further breakthroughs will occur, researchers believe, to allow circuits to be built with dimensions beyond the presently perceived physical limits.

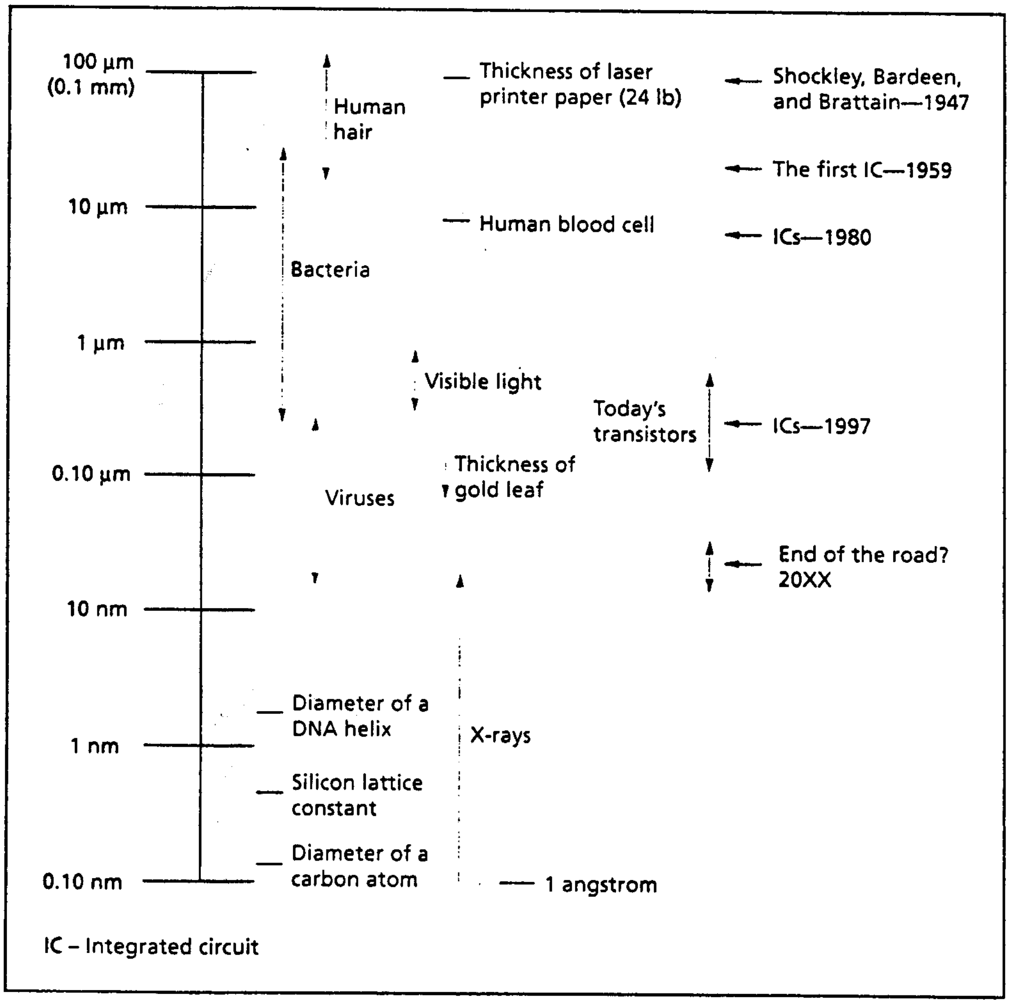
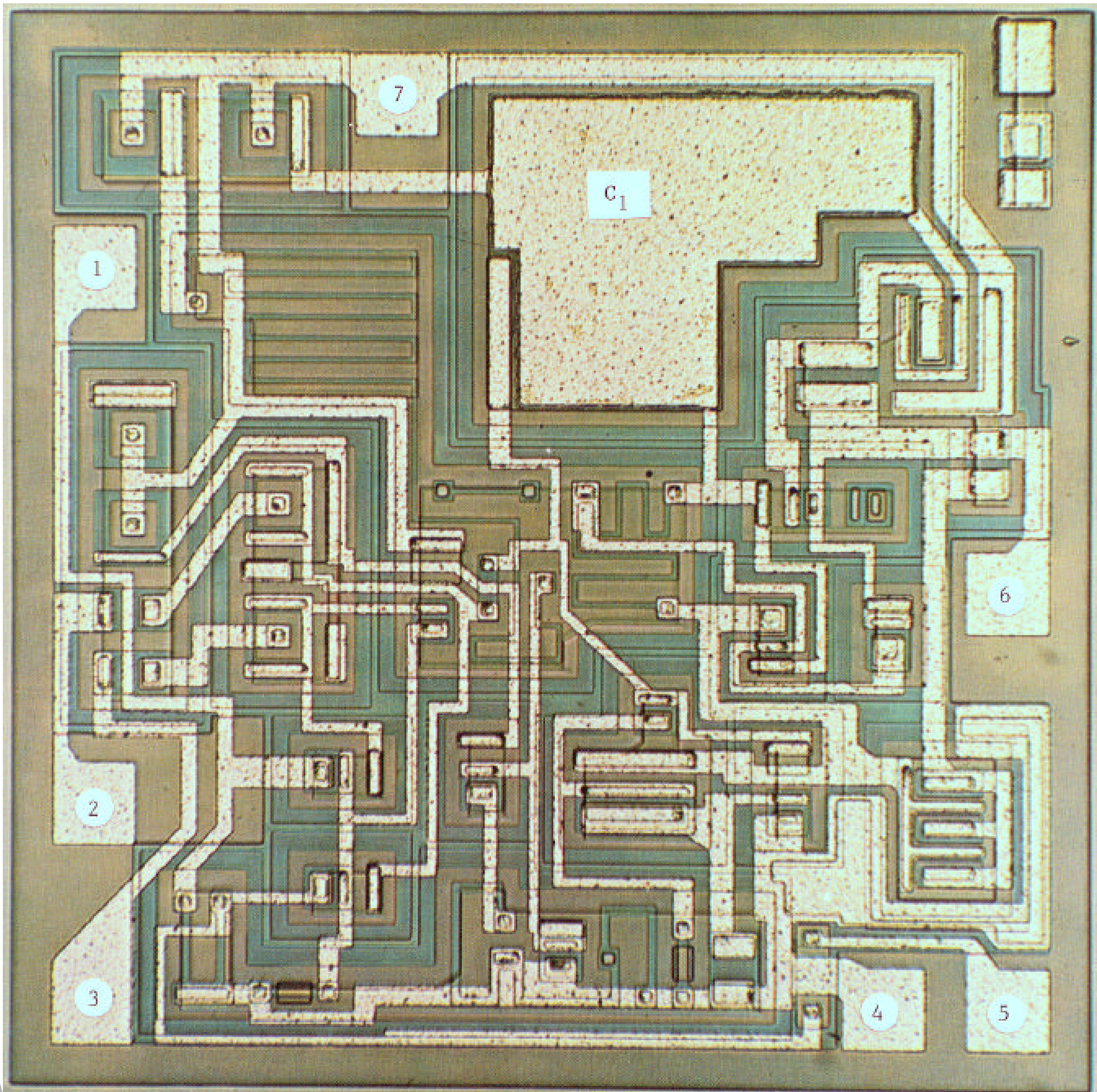


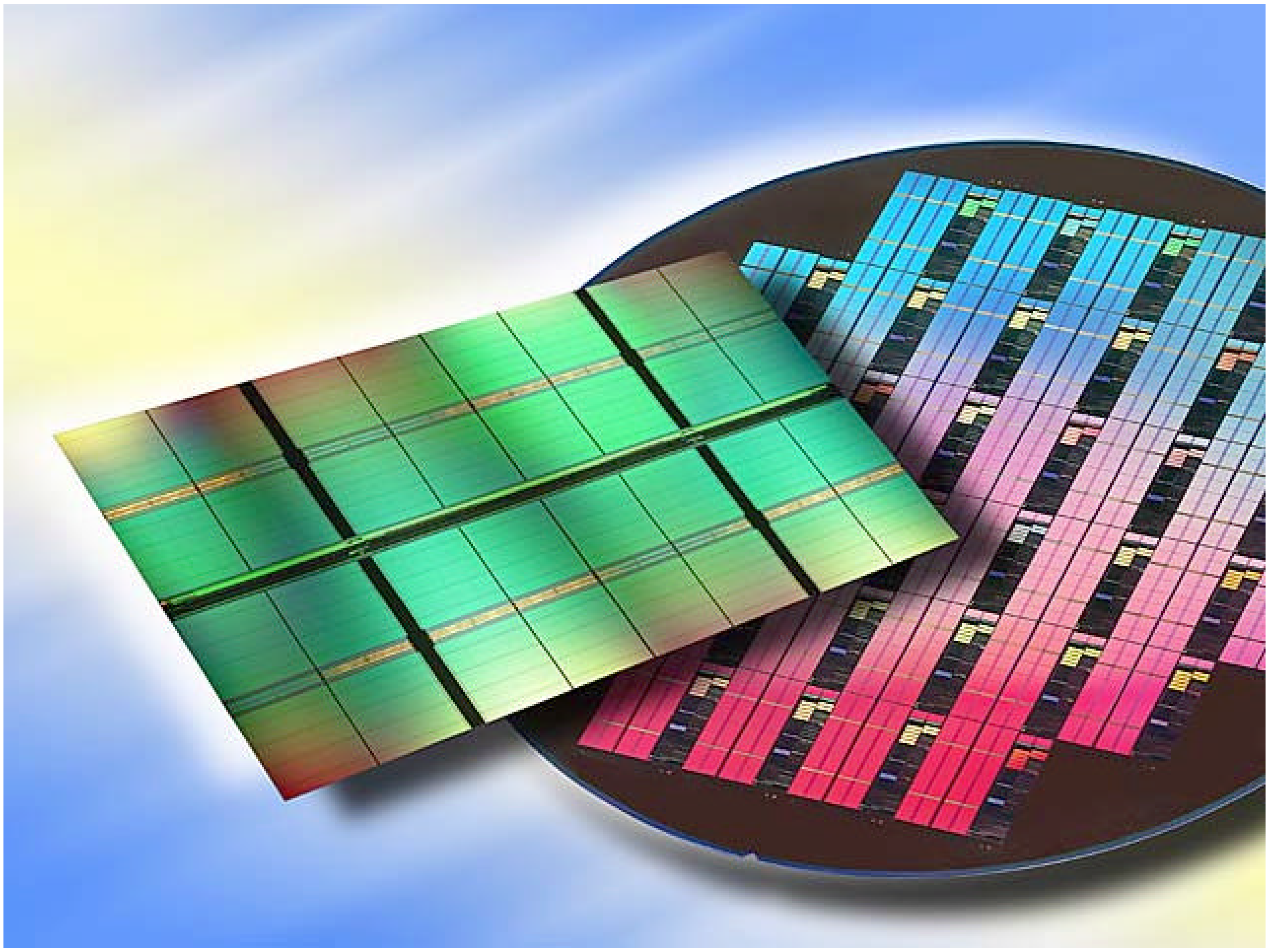
Figure 2.
The vanishingly small IC.

741 Operational Amplifier



1 Gbit DRAM

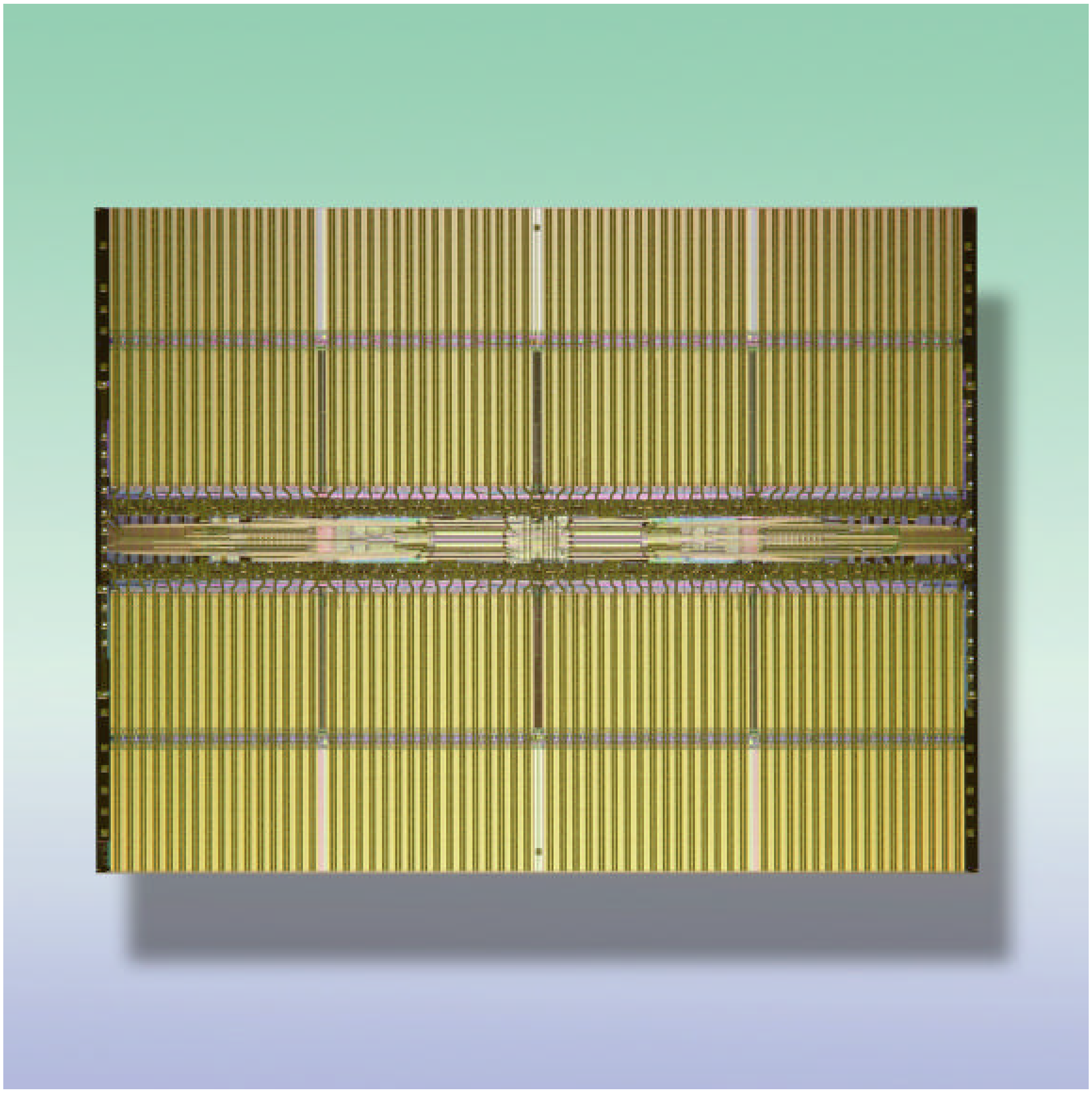
(Dynamic Random Access Memory)



Courtesy
Dr. Gary Bronner, IBM

8 Mb High Performance SRAM

(Static Random Access Memory)



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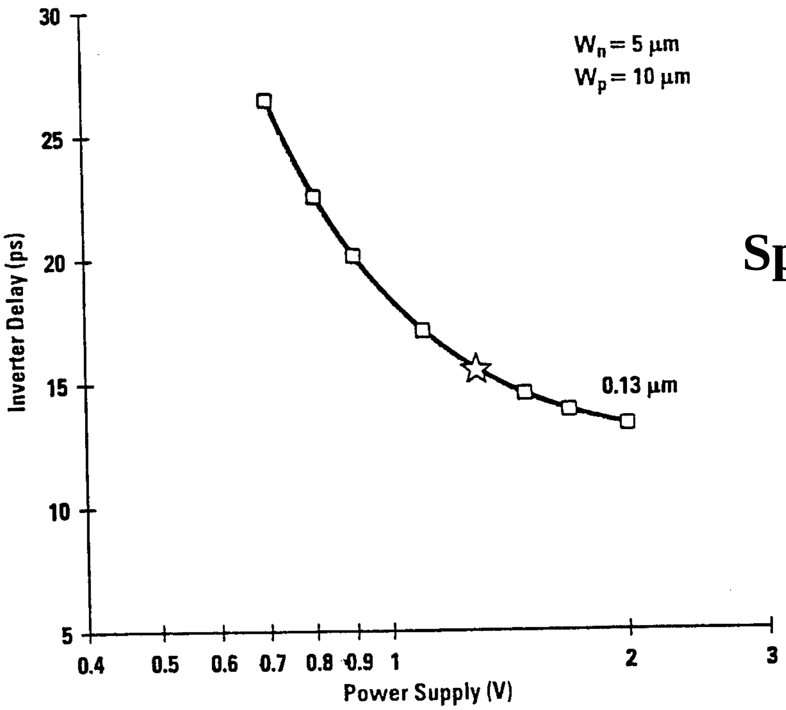
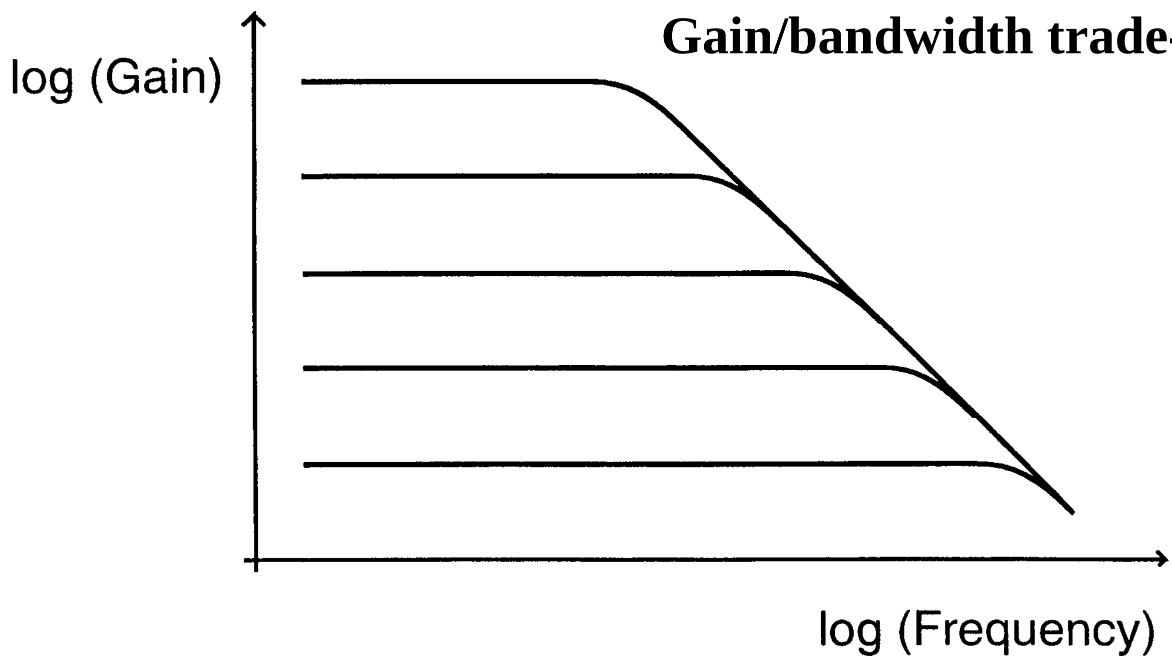
Circuit Engineering

- Simple first-order 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 tolerant to logic fluctuations and crosstalk
- Circuit design techniques to adapt to surroundings
  - Other circuits
  - Signal source
  - Transmission lines, etc
- Circuit design techniques that reduce power consumption

Trade-offs in Microelectronics



Speed/power trade-off

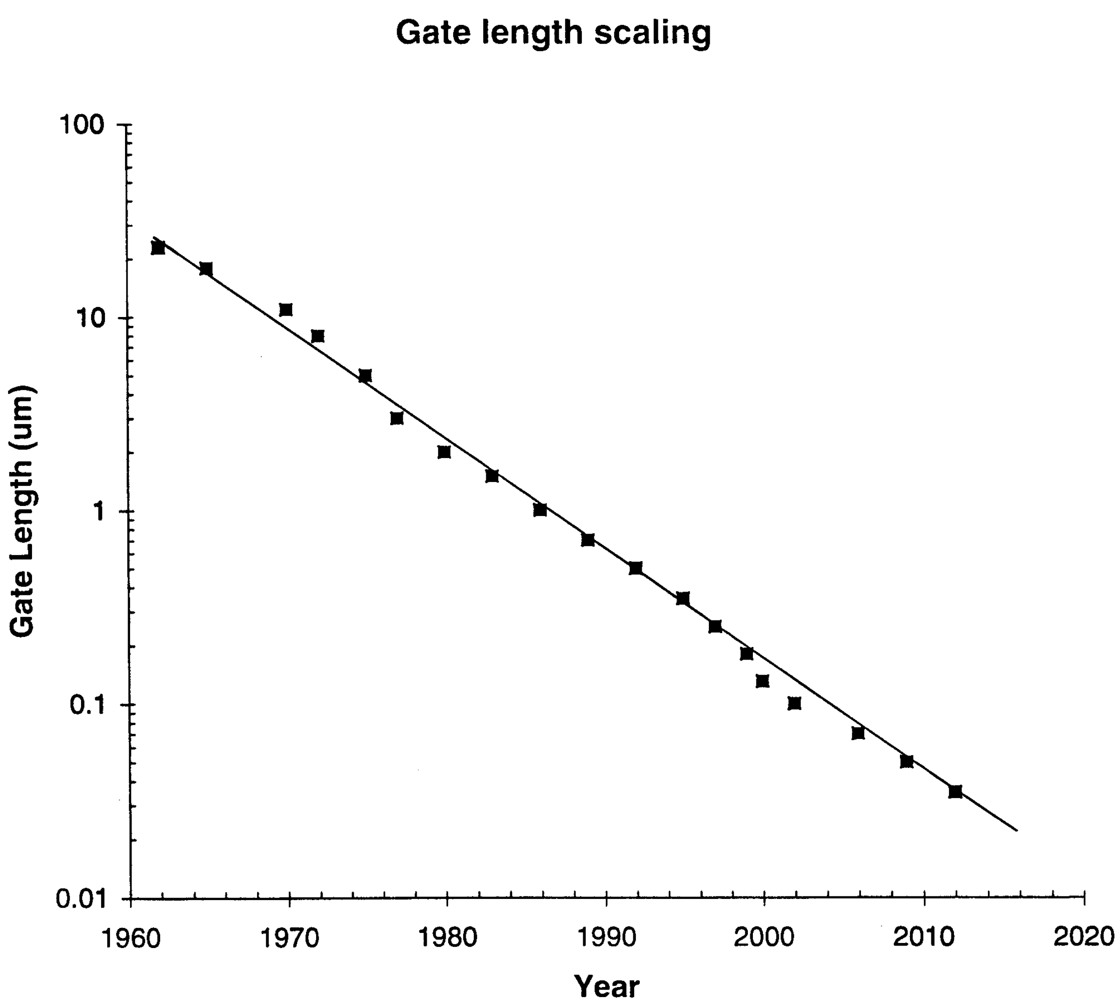


Gain/bandwidth trade-off

Beating These Trade-offs

Progress in Technology

- Scale down size of all components
- Reduce parasitics
- Novel circuit techniques to
  - Reduce power
  - Reduce number of components per function
  - Work around non-idealities of device



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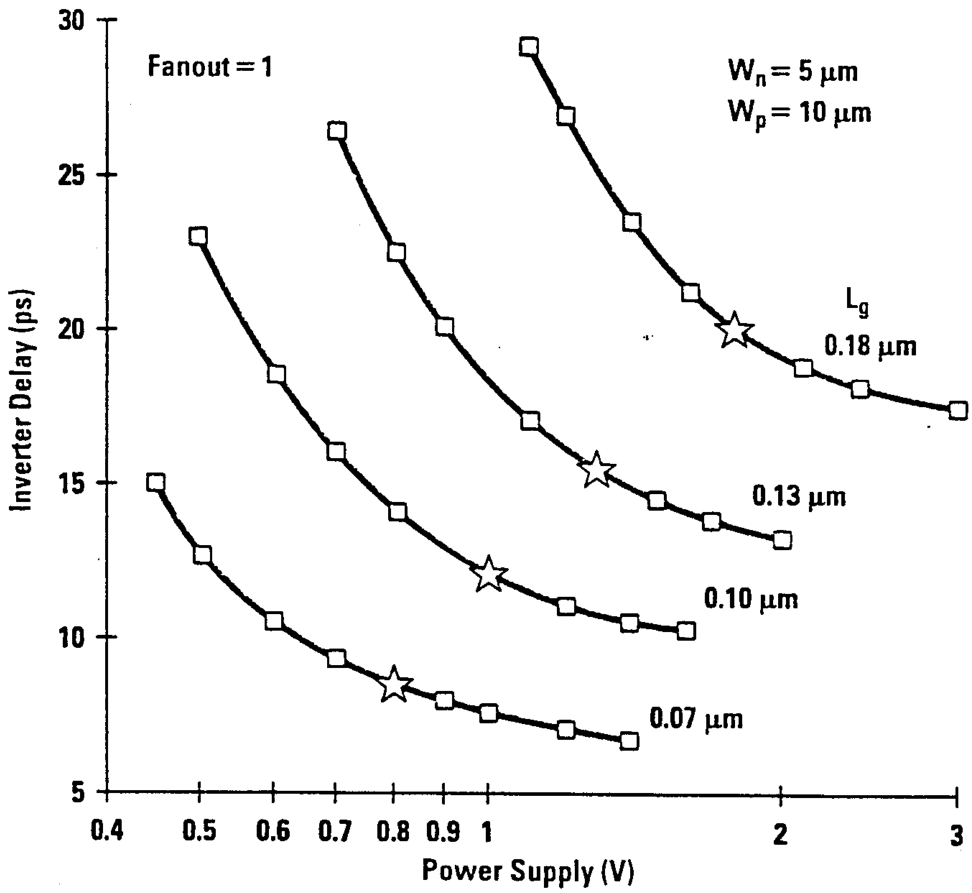
Voltage Scaling



Scaling

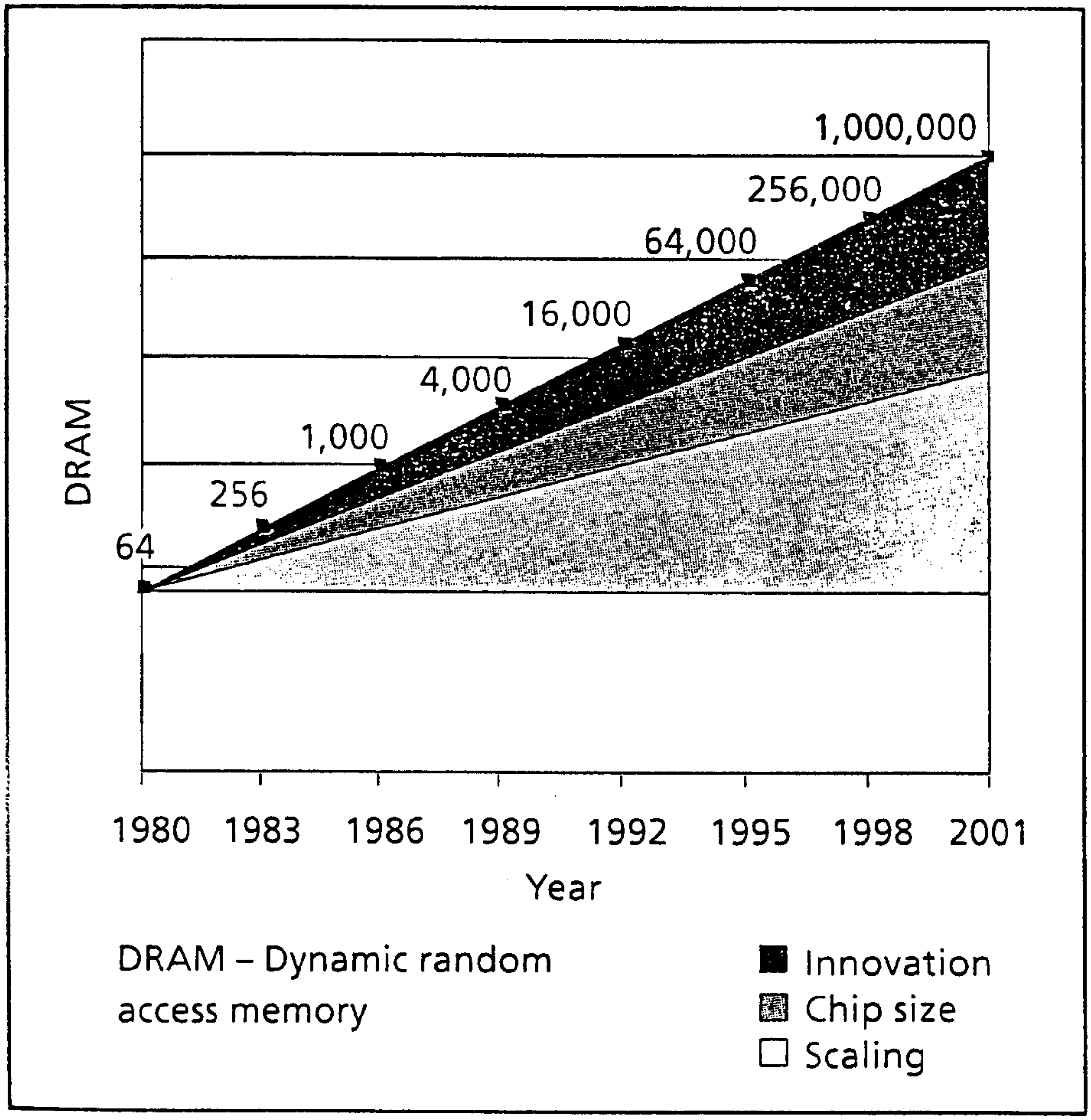


Figure 1.
Moore Plot showing the contribution of design innovation to the overall progress of IC fabrication.