Digital Circuits and Systems

Spring 2015 Week 1 Module 1

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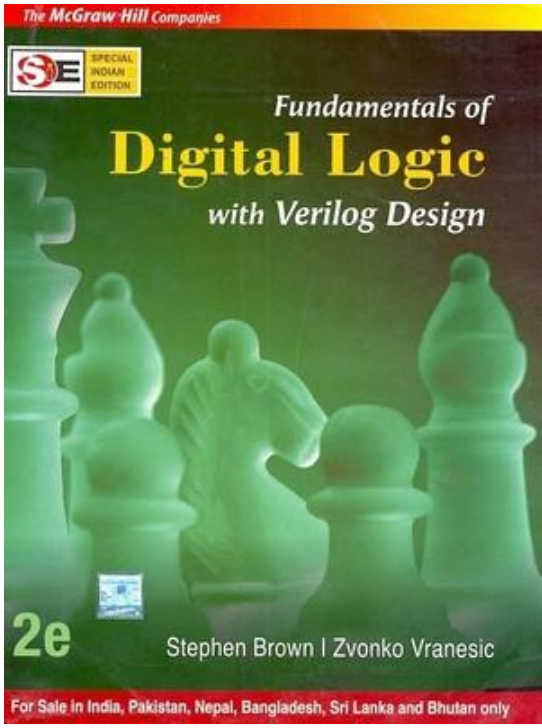
Course Overview

- To understand, analyze and design digital (logic) circuits.
- Basic logic theory, analysis and design of combinational and sequential logic circuits.
- Computer arithmetic circuits.
- Advanced topics in digital design.

- *Textbook*: *Fundamentals of Digital Logic with Verilog Design,*
  Stephen Brown and Zvonko Vranesic,
  McGraw Hill Publishing
  2nd Edition (Special Indian Version)
  ISBN: 9780070667242



General Information

- 8 Week Course
  - Intensive
- Course material, homework assignments, etc.:
  - All course announcements, homework assignments, etc. will be posted online
- Grading (tentative and subject to change)
  - Homework 50%
  - Final Examination 50%
- Follow the class forum carefully
  - Do not flame, flood or foul-mouth.

Homework Assignments

- Every week
- Posted on the website
- Sometimes, you will also be given do it yourself problems
  - Not graded and not part of the assignments
- Homework problems will give you good practice and reinforce concepts learnt in the class.

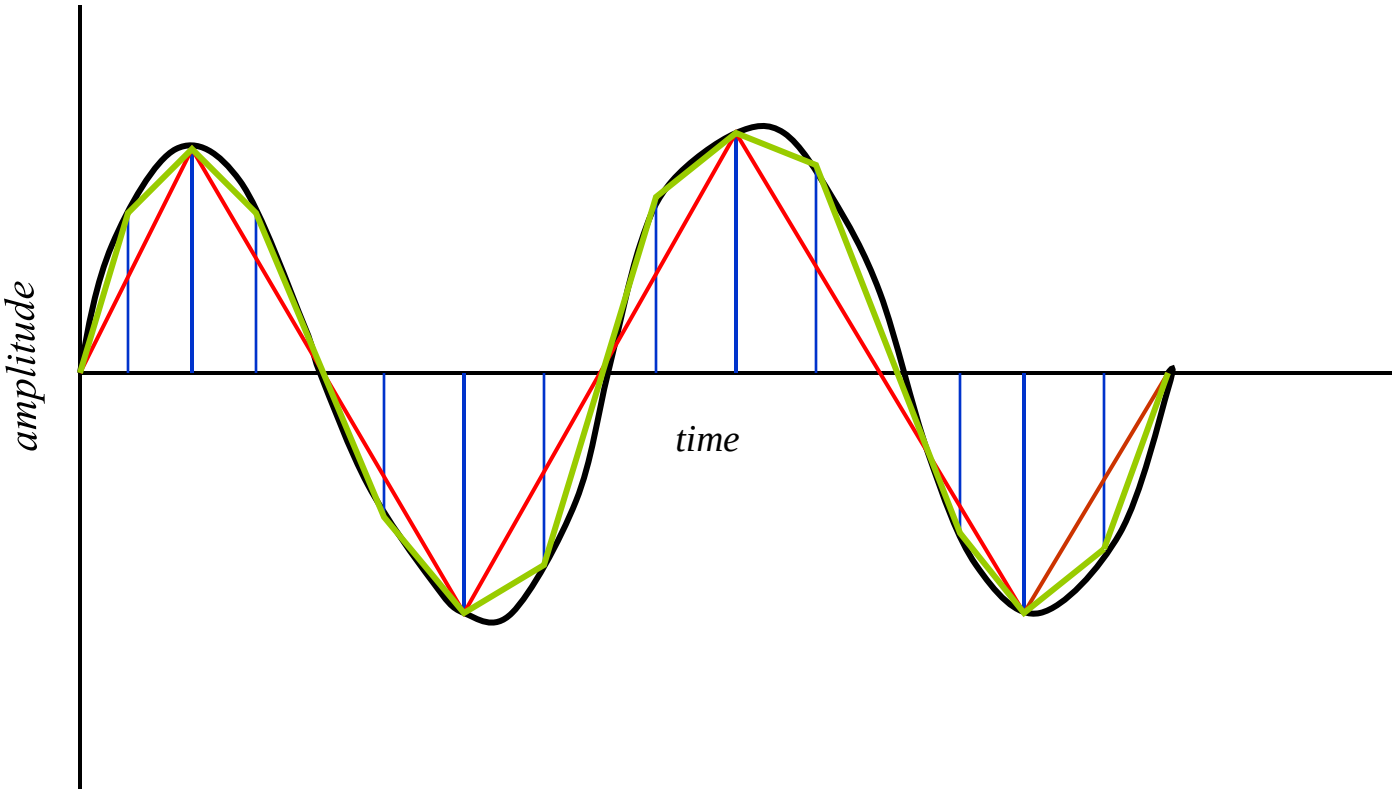
Motivation

- Many scientific, industrial and commercial advances have been made possible by the advent of computers.
- Few current engineering projects of any real complexity could be completed without the use of computers.
- The general-purpose *digital* computer is the best known example of a *digital system.*
- Other examples: digital telephones, switching exchanges, digital displays, calculators, video games, clocks, learning toys, digital control systems, home appliances, etc.
- All computers and other digital systems operate using the same concepts that will be presented in this class – The only difference is in the complexity of the circuits.

Digital versus Analog Systems

- In a *digital* system information is represented and processed in *discrete* rather than continuous forms.
- Systems based on *continuous* forms of information are called *analog* systems
- For example,
  - Information on traditional audio cassette tapes is recorded as a continuous analog signal.
  - Sample at uniform intervals to convert to discrete values and record in digital form

Continuous and Discrete



Advantages of Digital Systems

- Digital computers offer more flexibility than analog computers, i.e., they are easy to program to perform any desired algorithm.
- It is relatively easier to design high speed digital circuits.
- Numeric information can be represented digitally with greater precision and range than it can with analog signals.
- Given the same set of inputs, a properly designed digital circuit always produces precisely the same results. The outputs of an analog circuit may vary with temperature, supply voltage, component aging, and other factors.

Advantages (contd...)

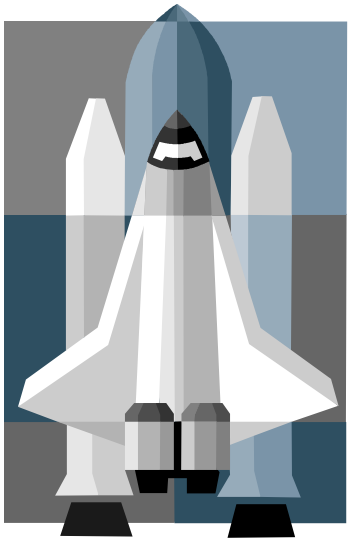
- Information storage and retrieval functions are much easier to implement in digital form than in analog.
- Digital techniques allow the use of built-in error detection and correction mechanisms.
- Digital systems lend themselves to miniaturization more than do analog systems. They can provide a lot of functionality in a small space.

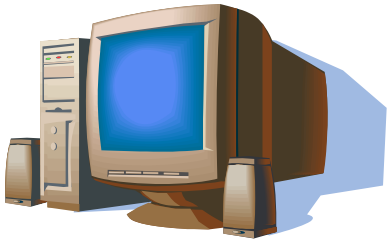
Disadvantages of Digital Systems

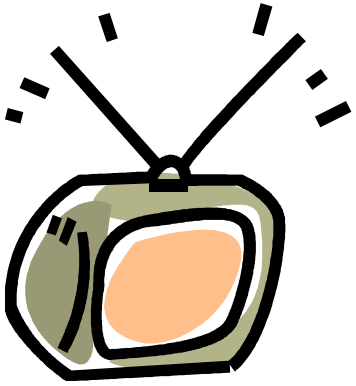
- World outside a digital computer is analog!

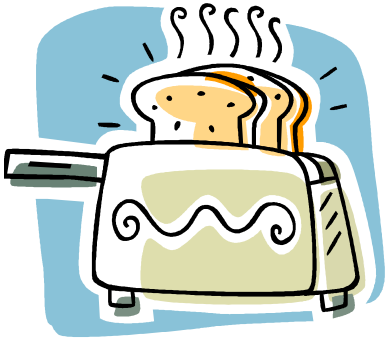
- Solution:
  - Input: Analog-to-Digital (A/D) converter at the input end.
  - Processing: Done using a digital system.
  - Output: Digital-to-Analog (D/A) converter at the output end.

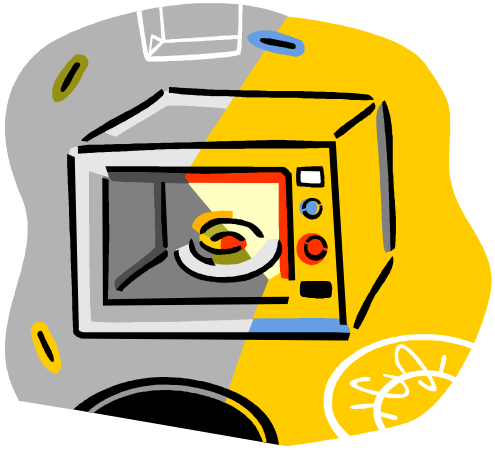
Where are These Systems?











General vs Specific Purpose

Course Overview

Background material which must be understood in order to discuss digital circuits - basic logic function, electrical properties of gates and combinational logic theory.

Design and analysis of combinational circuits,

Design and analysis of sequential circuits. These circuits are more complex because their output depends not only on the current input but also on input values from the past.

Design of arithmetic circuits

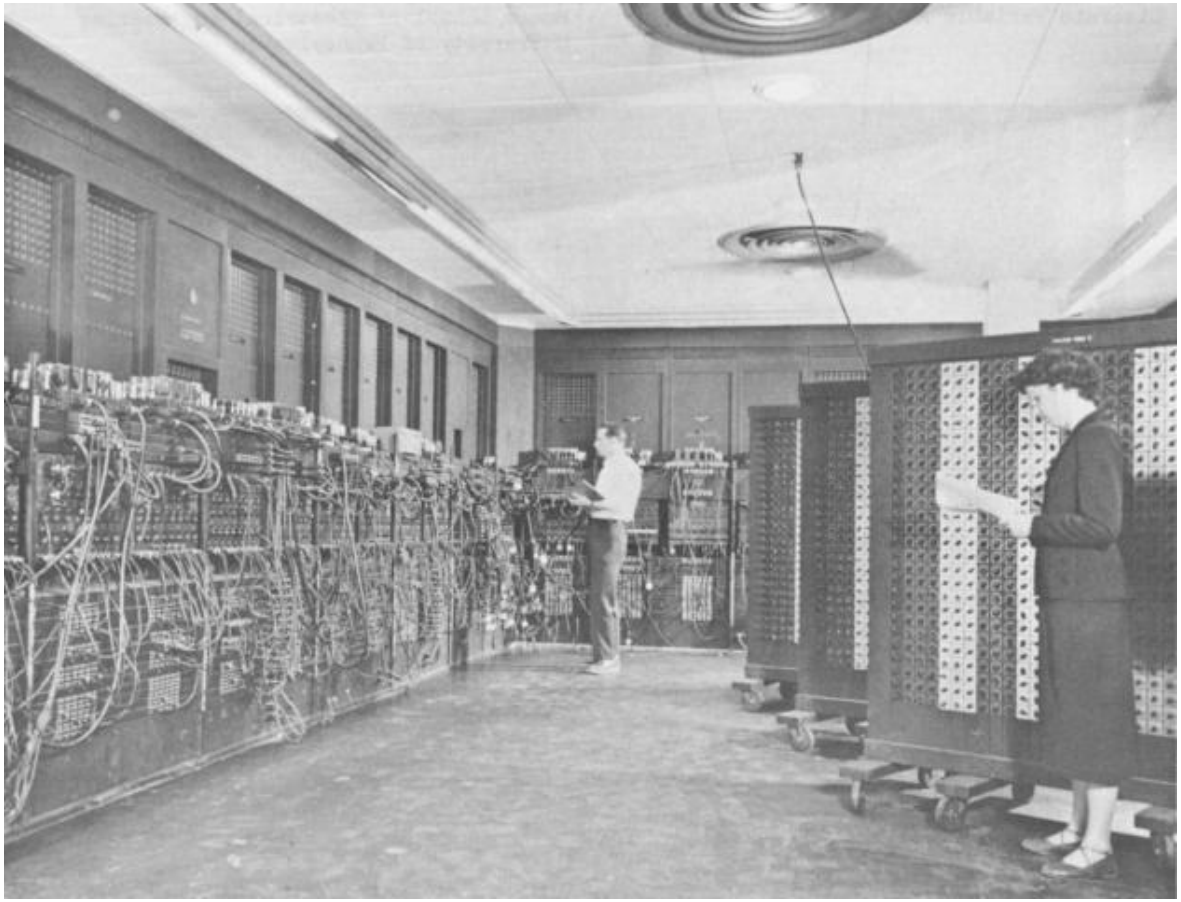
- Pipelining
- Timing Hazards
- Miscellaneous design issues.

Verilog Modeling

References

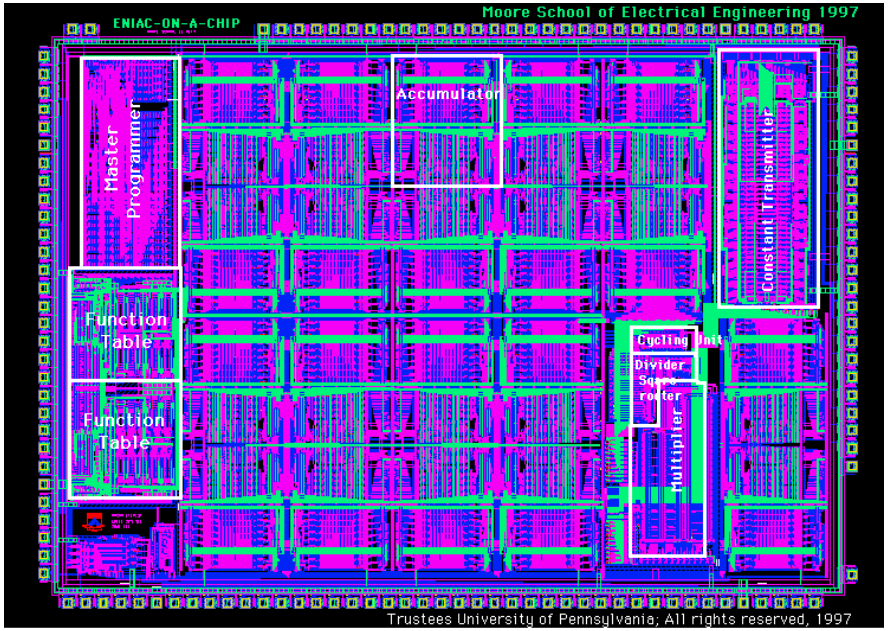
- S. Brown and J. Vranesic: "*Fundamentals of Digital Logic with Verilog Design*", McGraw Hill.
- J. Wakerly: *"Digital Design Principles and Practices,"* Prentice Hall.
- R. Katz: *"Contemporary Logic Design,"* Benjamin Cummings.
- M. Mano: "*Digital Design*", Prentice Hall.

How Chips Have Shrunk



- 1946 in UPenn
- Measured in cubic ft.

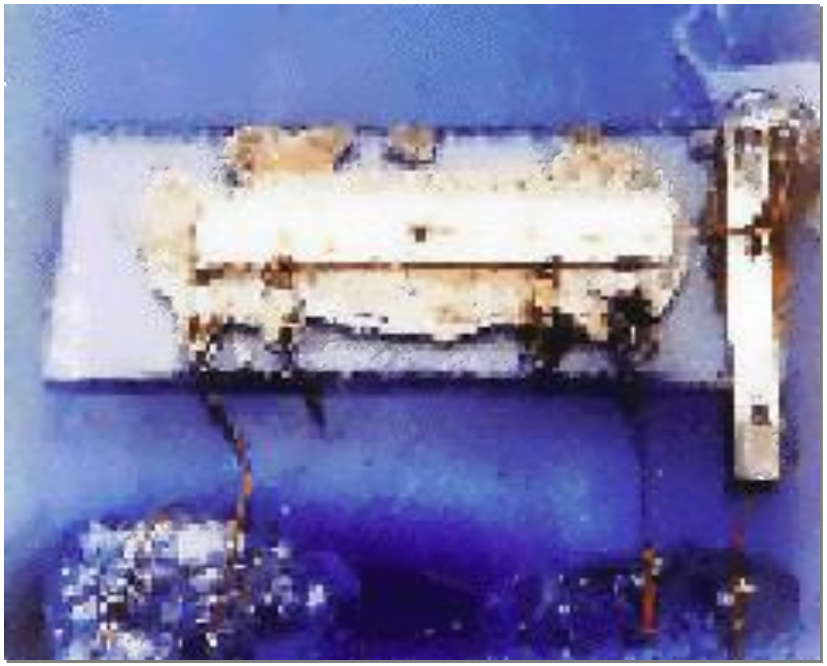
ENIAC on a Chip

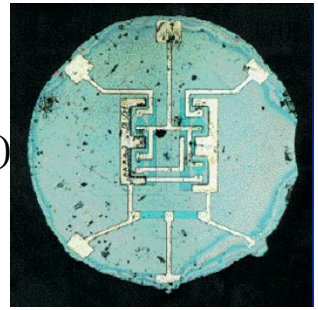


- 1997
- 174,569 Transistors

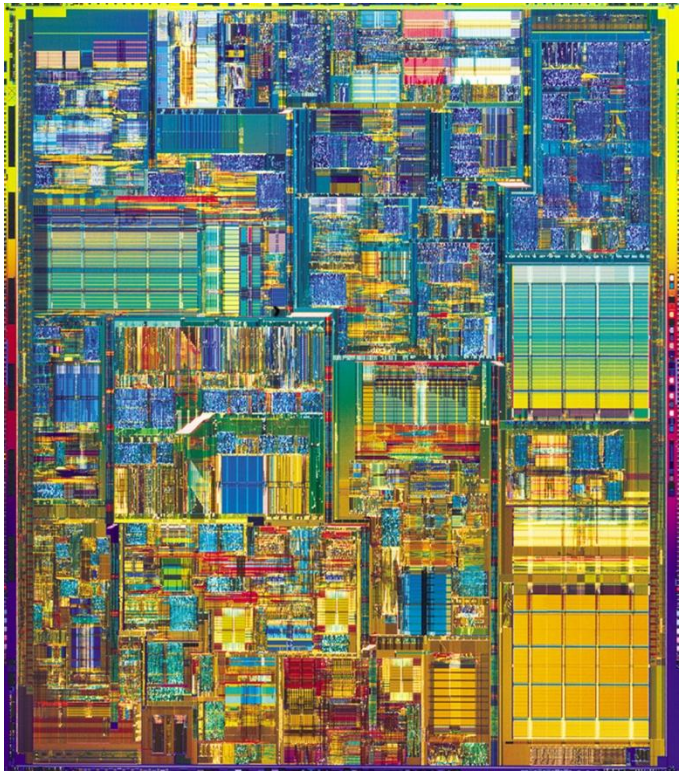
- 7.44 mm x 5.29 mm
- 0.5μ technology

Integrated Circuit Revolution



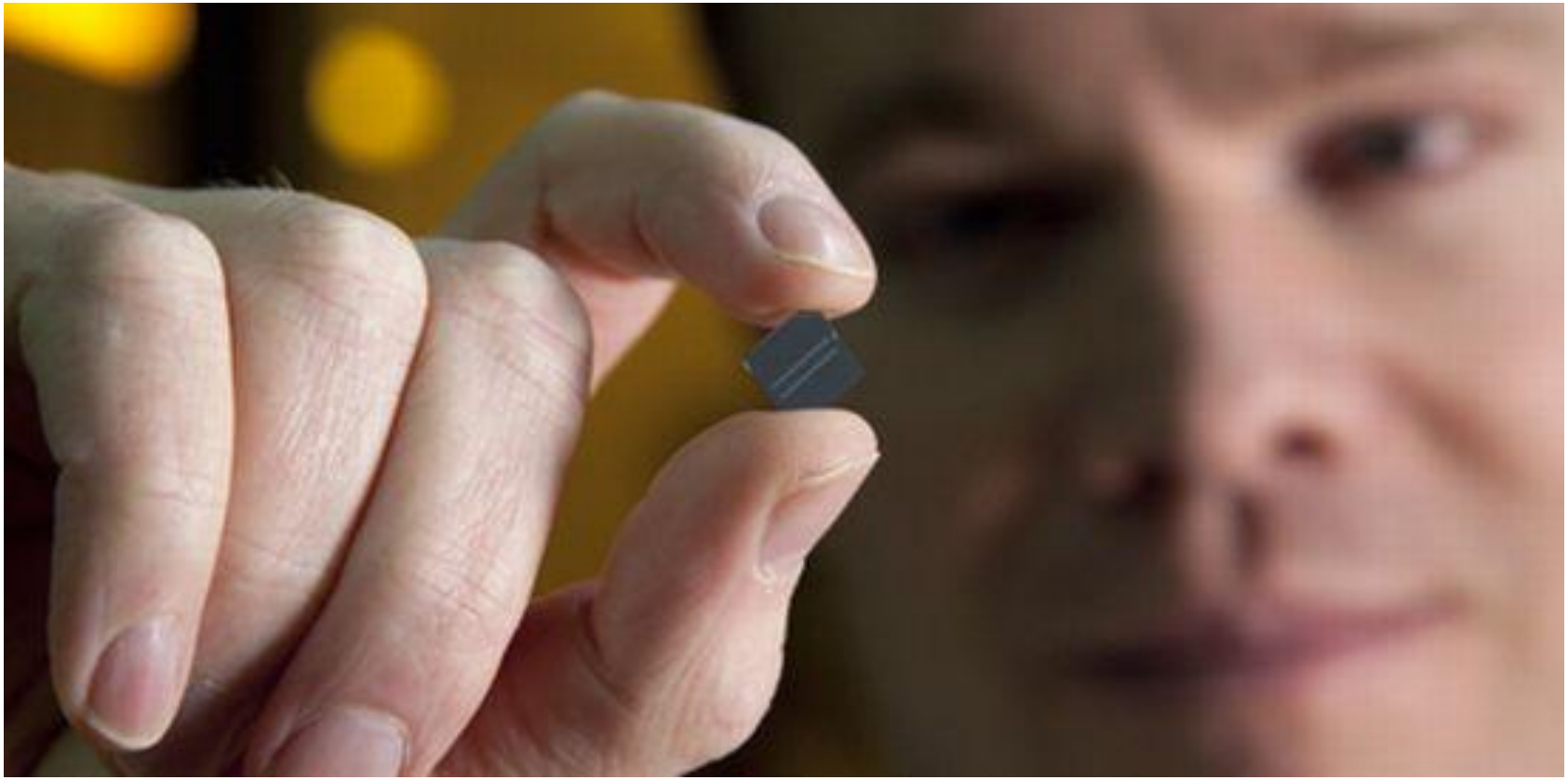


1958: First integrated circuit (germanium)
Built by Jack Kilby at Texas Instruments
Contailed five components : transistors, resistors and capacitors

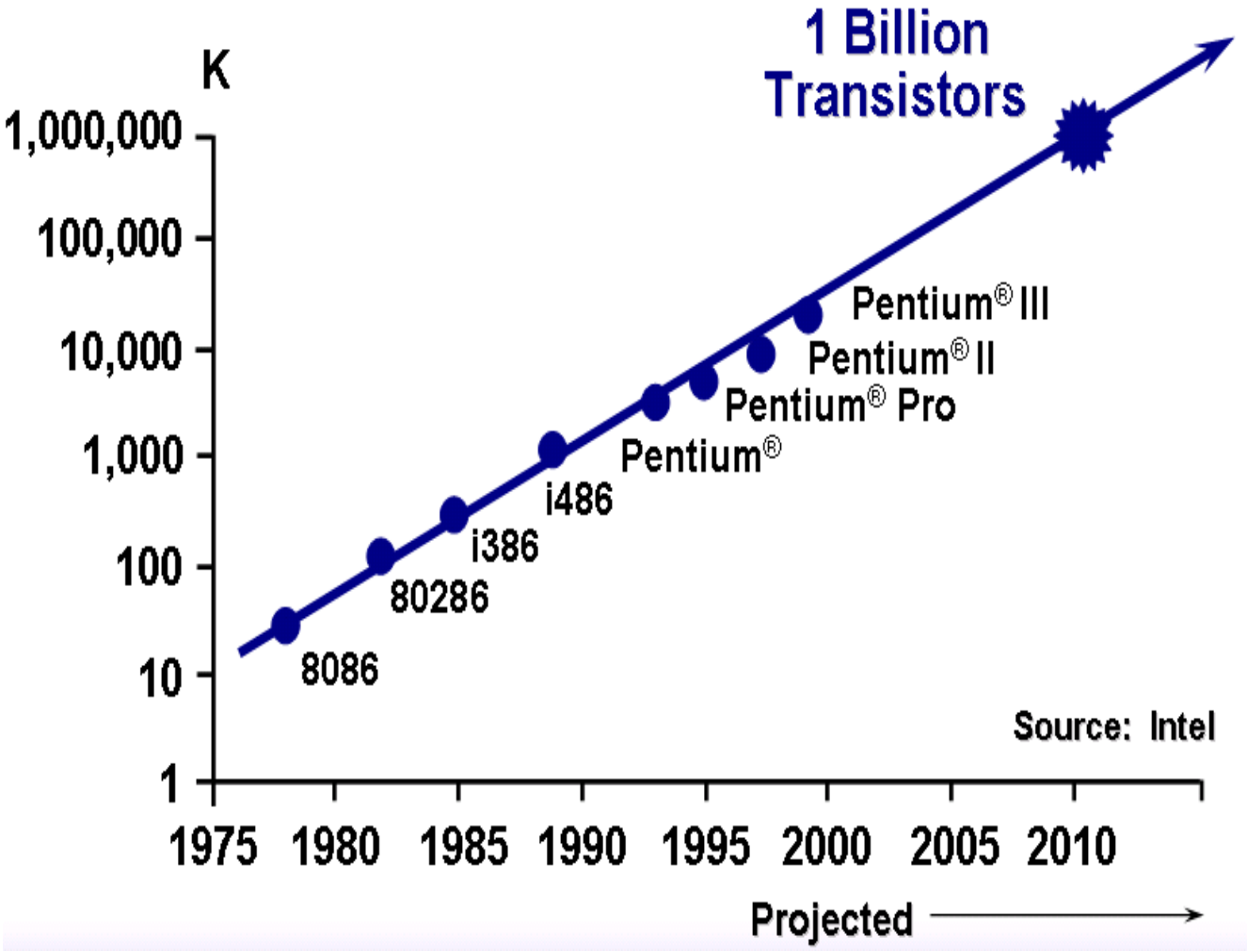


2000: Intel Pentium 4 Processor
Clock speed: 1.5 GHz
Transistors: 42 million
Technology: 0.18µm CMOS

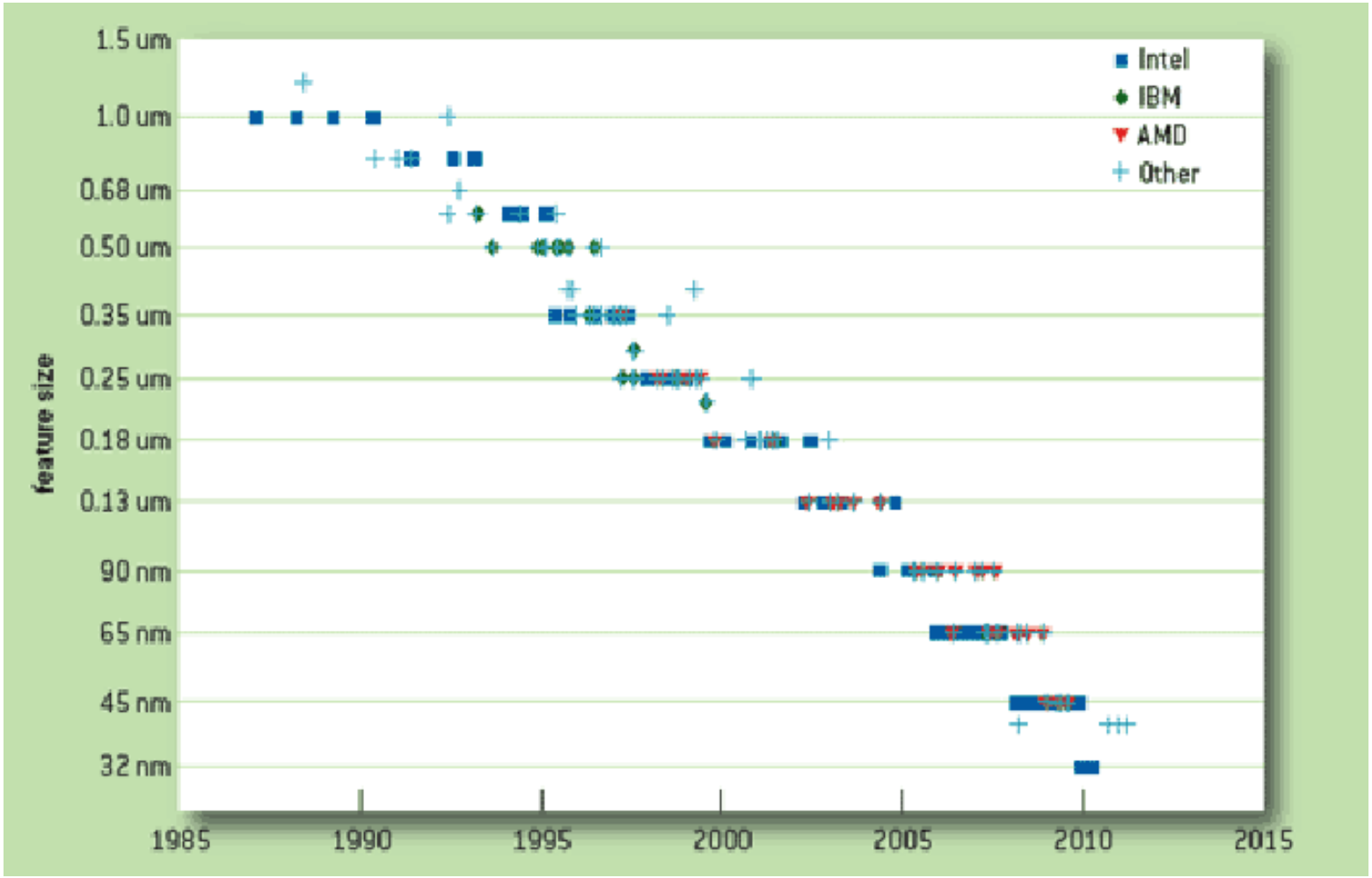
Microchip



Evolution in IC Complexity



Transistor Sizes Over Time

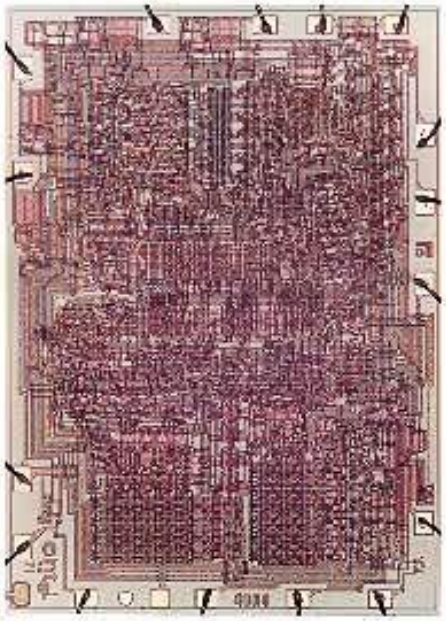


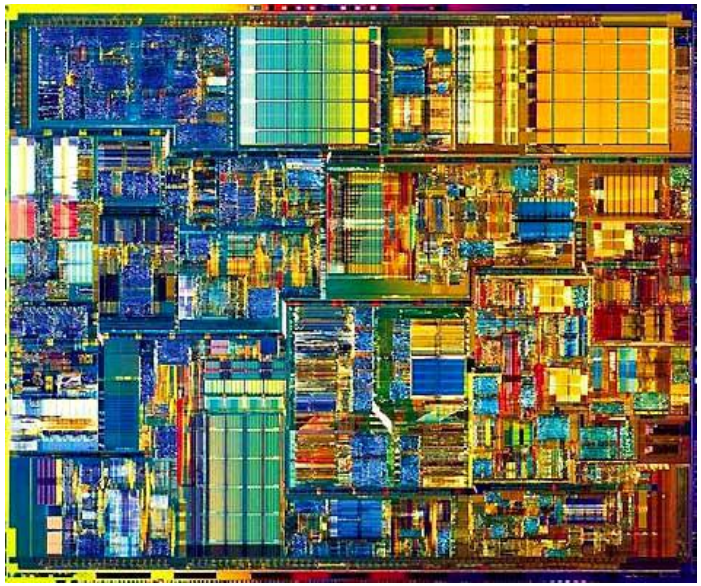
- Compare that to diameter of human hair - 56 um

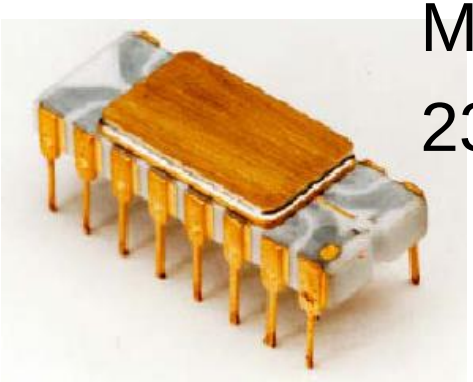
Intel 4004 vs. Pentium 4

Made in 2000

42M Transistors

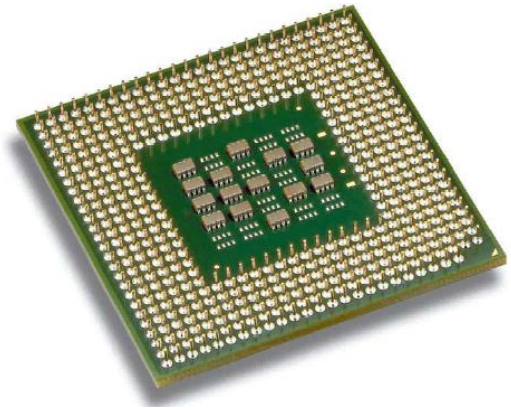






Made in 1971

2300 Transistors

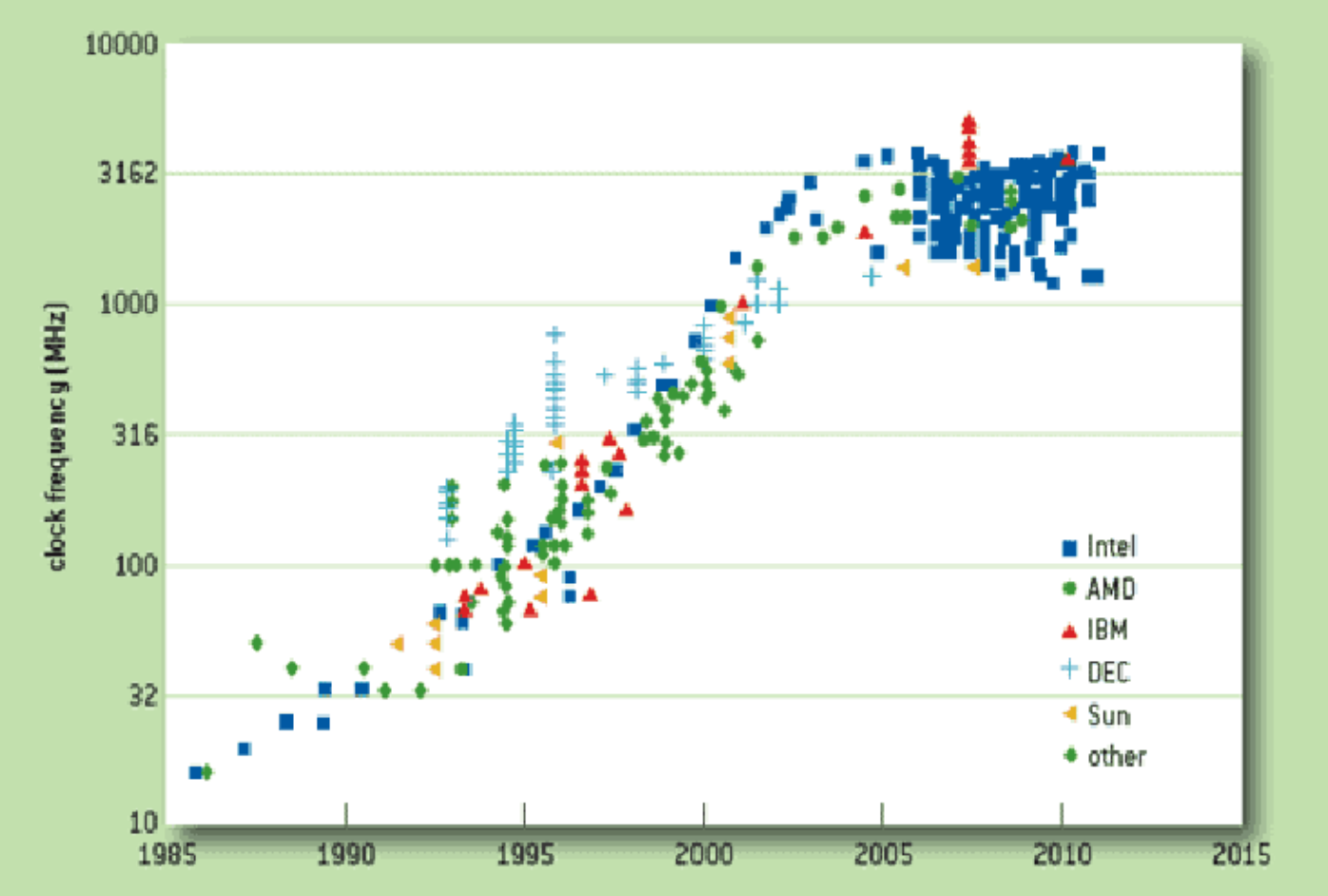


Moore's Law

- Transistors double almost every 2.3 years
  - Gordon Moore of Intel
  - Visionary prediction
  - Observed in practice for almost 4 decades
- Implication
  - More functionality
  - More complexity
  - Cost ??

Gordon Moore
Intel Co-Founder and Chairmain Emeritus
Image source: Intel Corporation www.intel.com

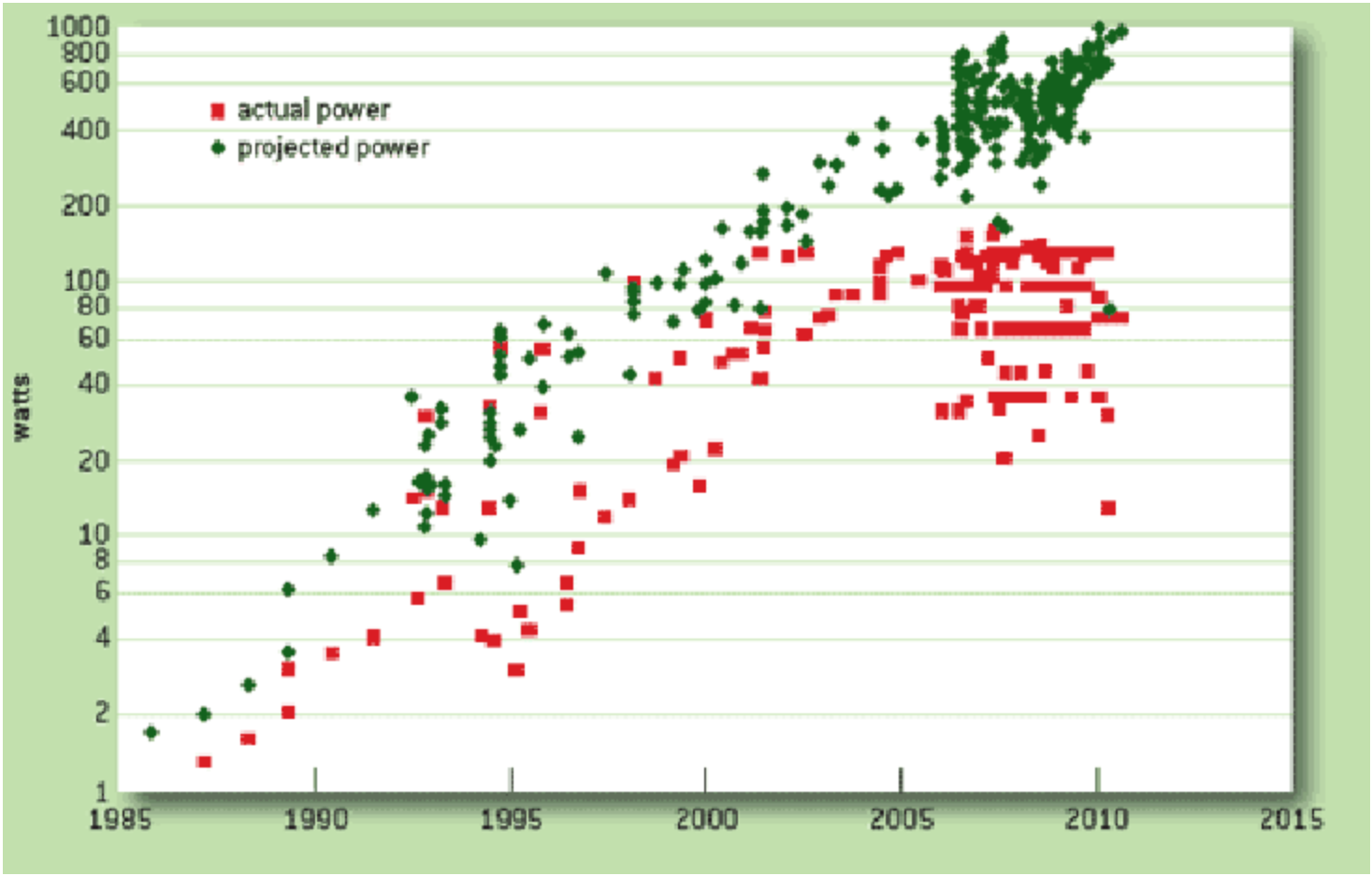
Processor Frequency Trends



Frequency doubles each generation*

*roughly

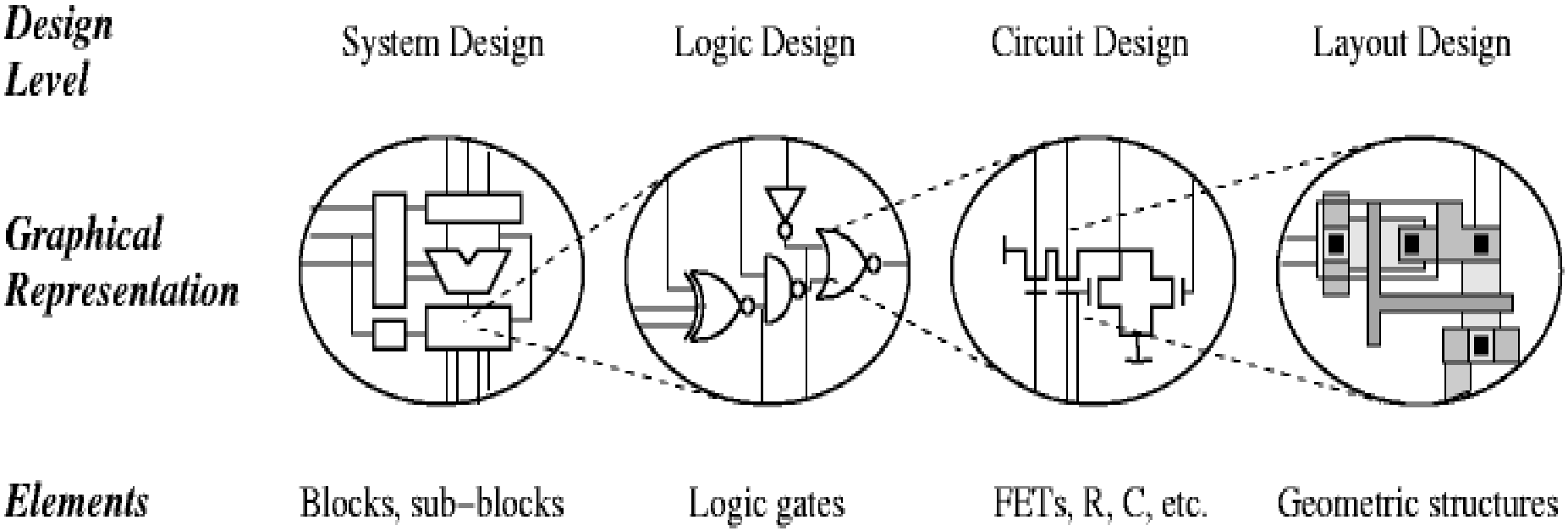
Power Scaling (Projected and Actual)



Scaling

- The process of shrinking the layout in which every dimension is reduced by a factor is called **Scaling**.
- Transistors become
  - Smaller, faster and consume less power
- Designs have smaller die sizes, higher yield and increased performance.

How to Handle Complexity?



Famous Quotes

- IBM founder T. J. Watson in 1945
  - “I don’t think there will ever be a market for more than 5 computers in this world.”
- Ken Olsen, president of Digital Equipment Corp. 1977
  - “There is no reason for any individual to have a computer in his home.”
- Lord Kelvin in 1895
  - “Heavier than air flying machines are not possible.”
- Bill Gates in 1981
  - “640 Kbytes of memory ought to be enough for anybody.”

Reading Material

- April 6, 2012 issue of ACM Queue
  - **CPU DB: Recording Microprocessor History**
  - http://queue.acm.org/detail.cfm?id=2181798
  - Some figures in this presentation are from that article.

End of Week 1: Module 1

Thank You