EE4415:
Integrated Circuits Design

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Course Websites & Ref. Books

- http://ivle.nus.edu.sg
- Jan M. Rabaey, Anantha Chandrakasan, and Borivoje Nikolic, "Digital Integrated Circuits", 2E, Prentice-Hall.
- Sung-Mo Kang, and Yusuf Leblebici, "CMOS Digital Integrated Circuits: Analysis and Design", 3E, McGraw Hill.
- Himanshu Bhatnagar, "Advanced ASIC Chip Synthesis Using Synopsys Design Compiler,Physical Compiler, and PrimeTime", Kluwer Academic Publishers, 2002.
- Stephen Brown Zvonko Vranesic, "Fundamentals of Digital Logic with Verilog Design", McGraw Hill.

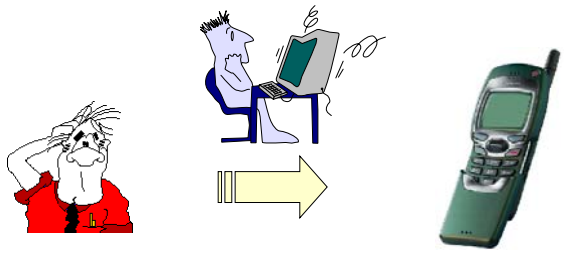
Topics Covered

The first part covers the digital IC design including:

- Introduction to IC design
- ASIC Design Methodology
- Synthesis Basics using Synopsys
- Design exercises = 30% CA

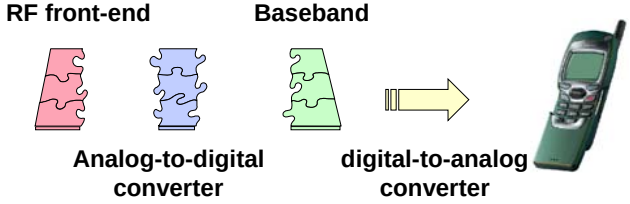
What Is IC Design ?

IC design is a process of the transformation of an idea into a manufacturable device that carries out an intended function.

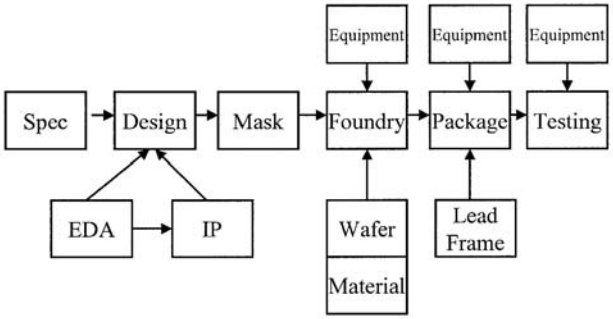


Design Classification

- Analog design.
- Mixed-Signal design.
- Digital design.

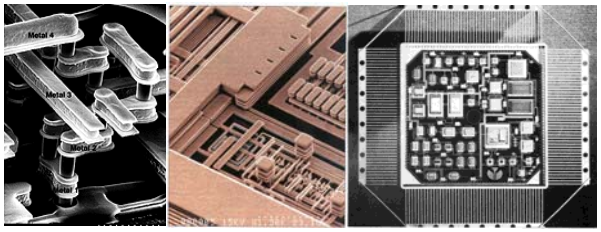


Semiconductor Industry



Introduction to Digital IC Design

- Why is designing digital ICs different today than it was before?
- Will it change in future?

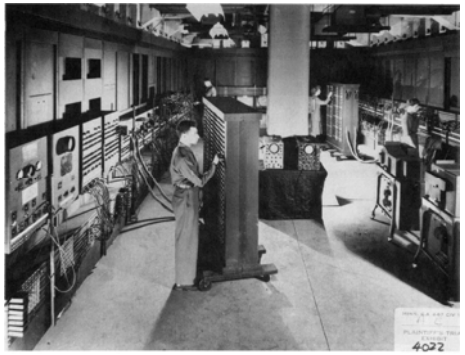


The First Computer

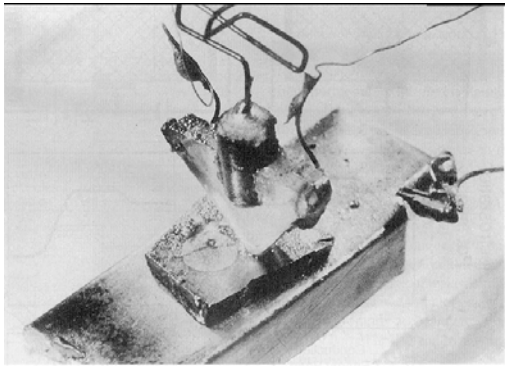
The Babbage Difference Engine (1832)

25,000 parts
cost: ? 7,470

ENIAC :
The first electronic computer (1946)

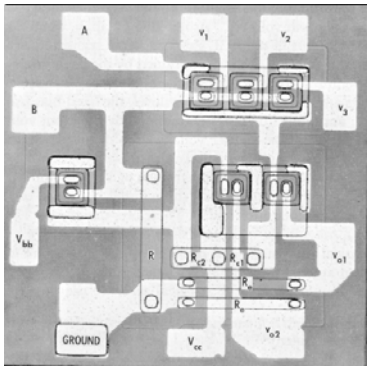


The Transistor Revolution



First transistor
Bell Labs, 1948

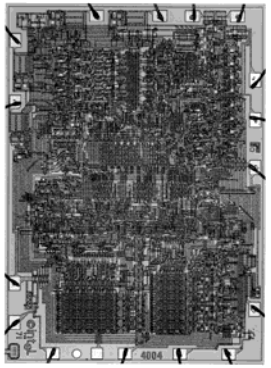
The First Integrated Circuits



Bipolar logic
1960's

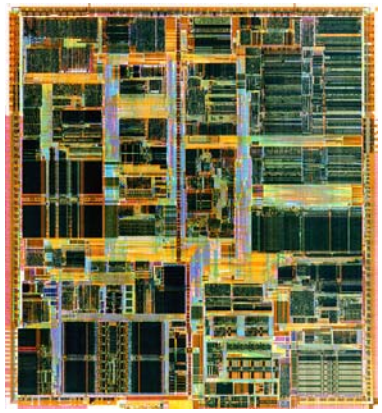
ECL 3-input Gate
Motorola 1966

Intel 4004 Micro-Processor



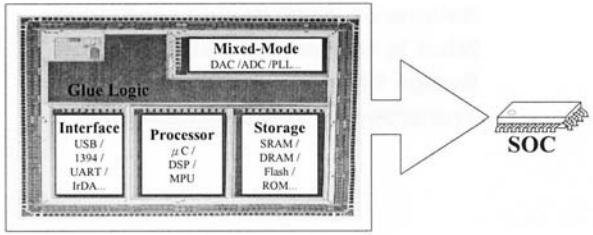
1971
1000 transistors
1 MHz operation

Intel Pentium (IV) microprocessor



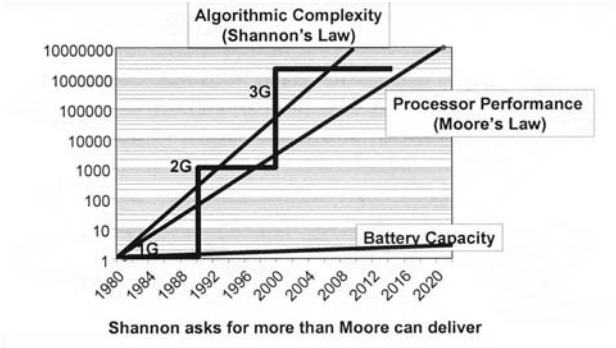
The Trend in IC Design

- System integration : moving from board to chip → System-on-Chip (SoC)
- What is SoC ?



The Challenges

- The algorithmic driving force →design complexity

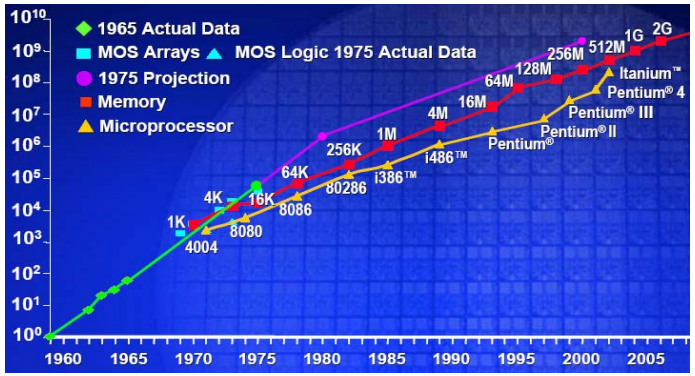


Moore's Law

- In 1965, Gordon Moore noted that the number of transistors on a chip doubled every 18 to 24 months.
- He made a prediction that semiconductor technology will double its effectiveness every 18 months

Number of Transistors per Die

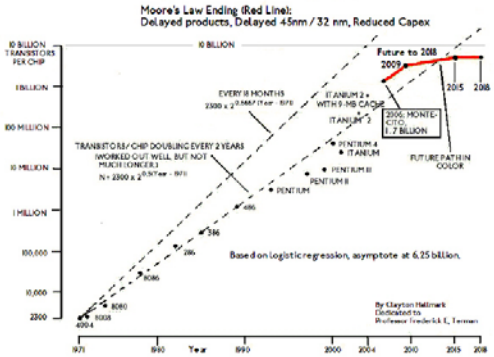
Source: ISSCC 2003 G. Moore "No exponential is forever, but 'forever' can be delayed"



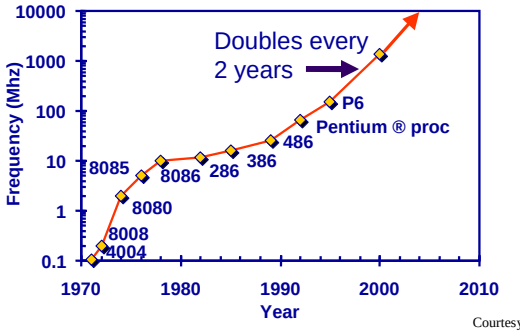
Moore's Law

	Year of introduction	Transistors
• 4004	1971	2,250
• 8008	1972	2,500
• 8080	1974	5,000
• 8086	1978	29,000
• 286	1982	120,000
• 386™	1985	275,000
• 486™ DX	1989	1,180,000
• Pentium®	1993	3,100,000
• Pentium II	1997	7,500,000
• Pentium III	1999	24,000,000
• Pentium 4	2000	42,000,000

Moore's Law Ending?

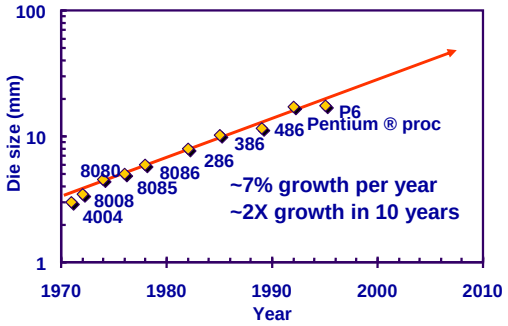


Microprocessor Clock Frequency



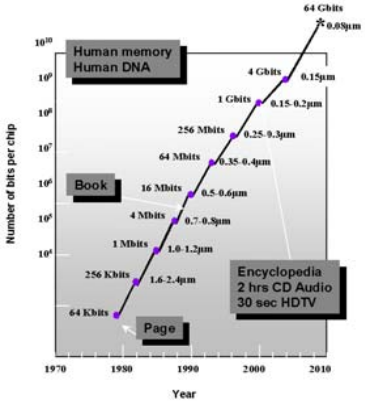
Courtesy of Intel

Die Size Growth

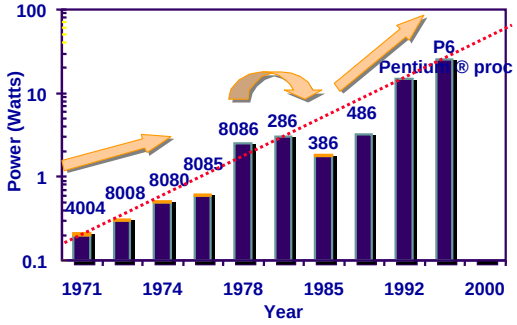


Courtesy of Intel

Evolution in Complexity

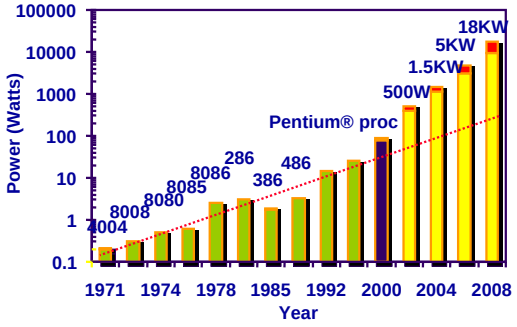


Power Dissipation



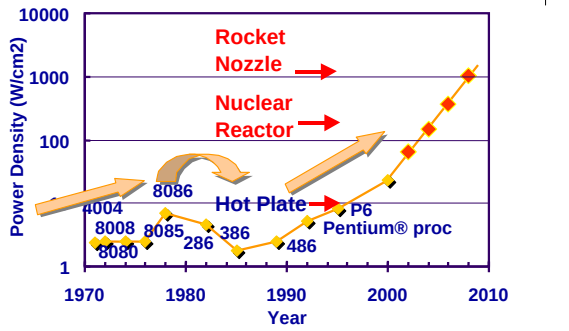
Courtesy of Intel

Power: a Major Problem



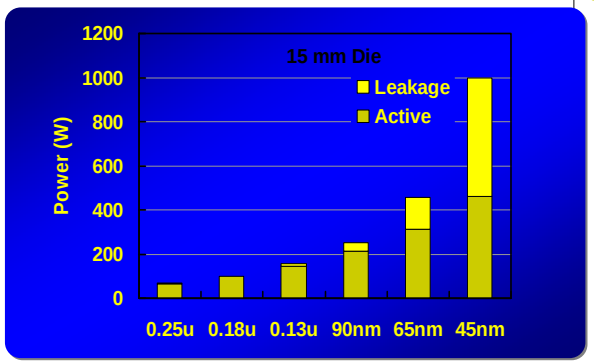
Courtesy of Intel

Power Density



Courtesy of Intel

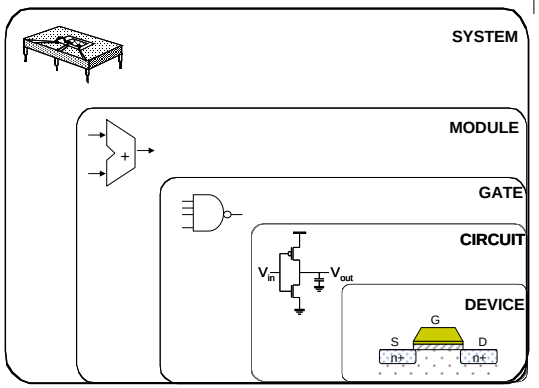
The Power Crisis



Technology Scaling

- Technology shrinks by ~0.7 per generation
- With every generation can integrate 2x more functions on a chip; chip cost does not increase significantly
- Cost of a function decreases by 2x
- But …
  - How to design chips with more and more functions?
  - Design engineering population does not double every two years…
- Hence, a need for more efficient design methods
  - Exploit different levels of abstraction

Design Abstraction Levels



Considerations in IC Design

- Chip size (cost)
- Operation speed (value)
- Power consumption (energy efficiency)
- Manufacturability
- Testability
- Reliability
- Time-to-market
- Constrains in design