DIGITAL SYSTEMS: ORIGINS AND PROGRESS

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CS & E: THE ORIGINS AND PROGRESS

- Millennia of interest in mechanizing thought process [Leibniz, ..., Boole, ..., Babbage, ..., Turing]

- Millennia of interest (and profit) in speeding up calculations [Leibniz, Pascal, Nappier, ..., artillery, ..., navy, ..., business, ..., gamers, ...,]

- Technology:
  - mechanical calculating machines: Leibniz, Pascal, Babbage (Analytical and Differential Engine)
  - electromechanical: relay-contact networks
  - electronics: vacuum tubes, transistors, integrated circuits -VLSI

- Theoretical foundations
  - Mathematical logic
  - Computability: Turing, Church
  - Algorithms and complexity analysis: Turing
  - Formal languages: Chomsky
  - Applied mathematical methods

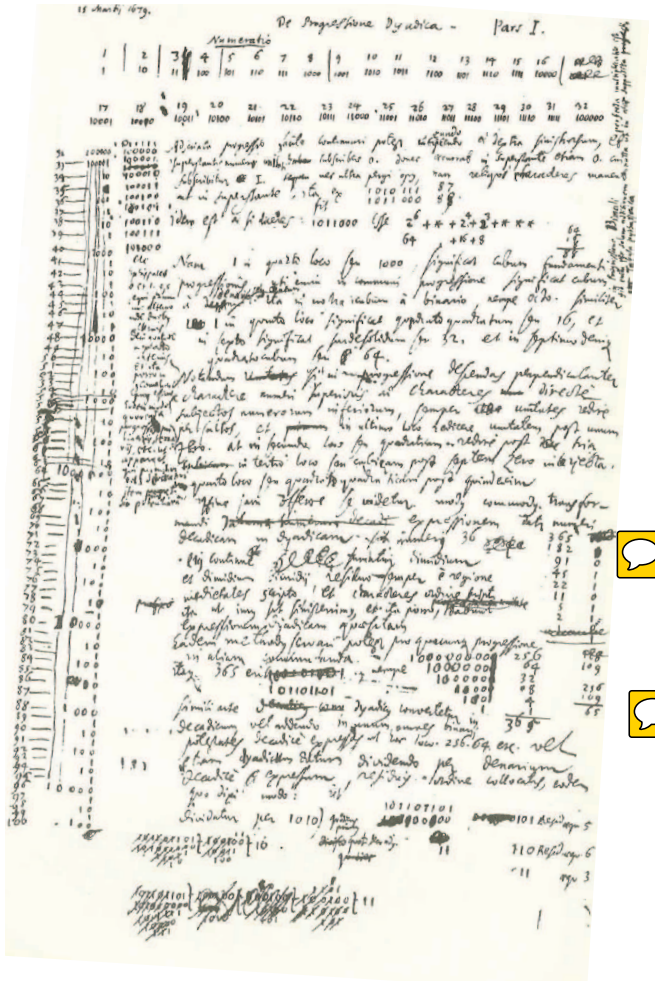
THE PIONEERS OF DIGITAL LOGIC

- Laid foundations of digital system design and analysis
- Gottfried Leibniz
- George Boole
- Claude Shannon

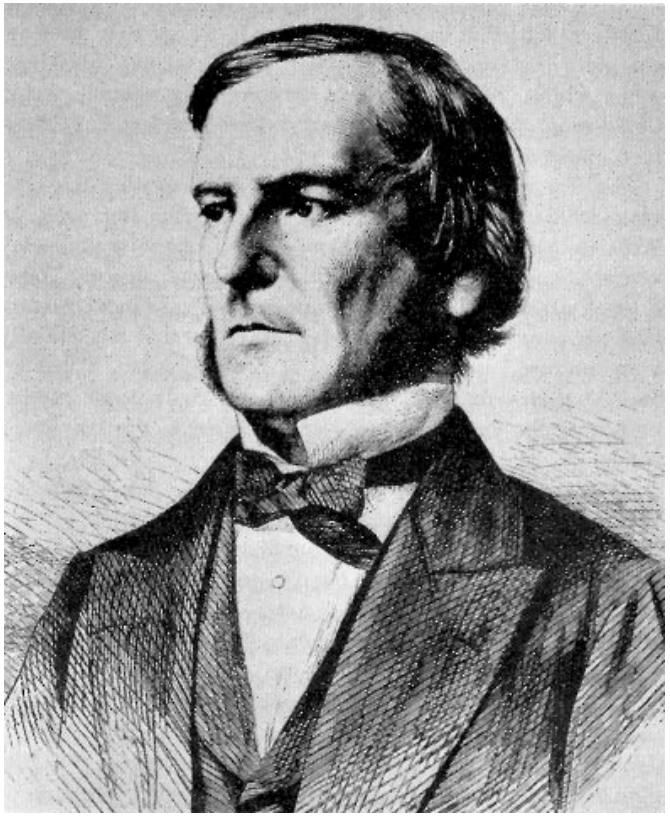
Gottfried Wilhelm Leibniz (1646 - 1716)

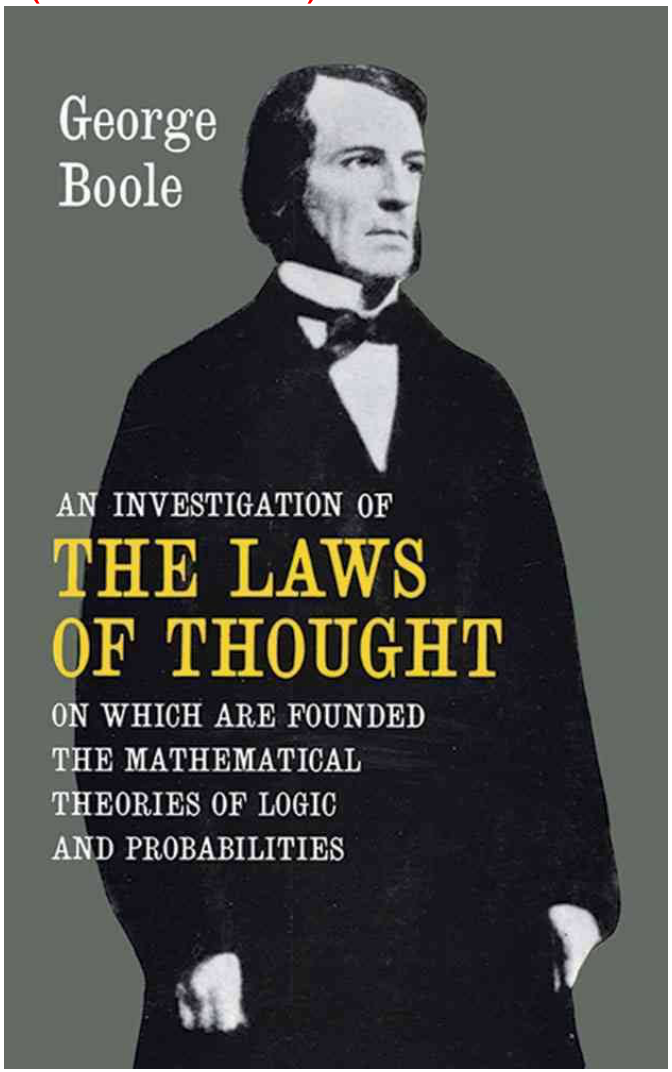
- Binary number system; Adding machine
- Symbolic logic
- Logic as universal language to mechanize thought
- Differential calculus - contemporary of Newton

Leibniz' Binary Representation



George Boole (1815-1864)





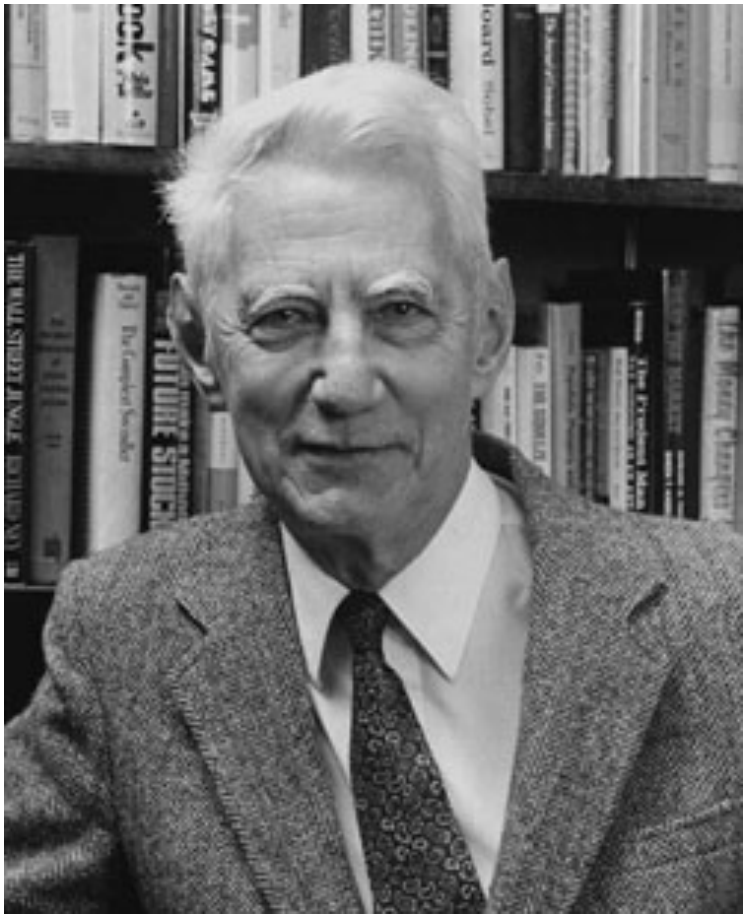
- Use of mathematics to solve logical problems

- Boolean Algebra

- Led to switching algebra

  - a formal basis for digital design

Claude Elwood Shannon (1916-2001)



- 1938 - Relates Boolean Algebra to networks of switches and defines

- Switching Algebra

  - a principal formal basis for digital design and analysis

  - made design of computers possible

- 1948 - Introduces information theory in

  ”Mathematical Theory of Communications”

  - a basis of communication systems

Shannon's MS Thesis applied Boolean Algebra to networks of switches:

A SYMBOLIC ANALYSIS

OF

RELAY AND SWITCHING CIRCUITS

by

Claude Elwood Shannon

B.S., University of Michigan

1936

Submitted in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

from the

Massachusetts Institute of Technology

1940

Signature of Author_____

Department of Electrical Engineering, August 10, 1937

Signature of Professor
in Charge of Research_____

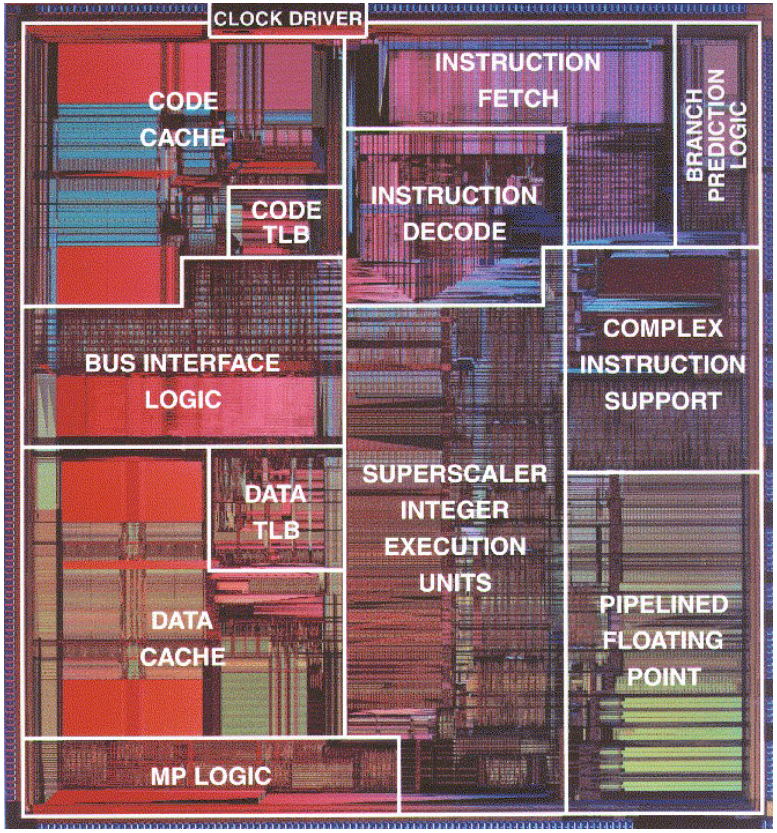
Signature of Chairman of Department
Committee on Graduate Students_____

HARDWARE TECHNOLOGY

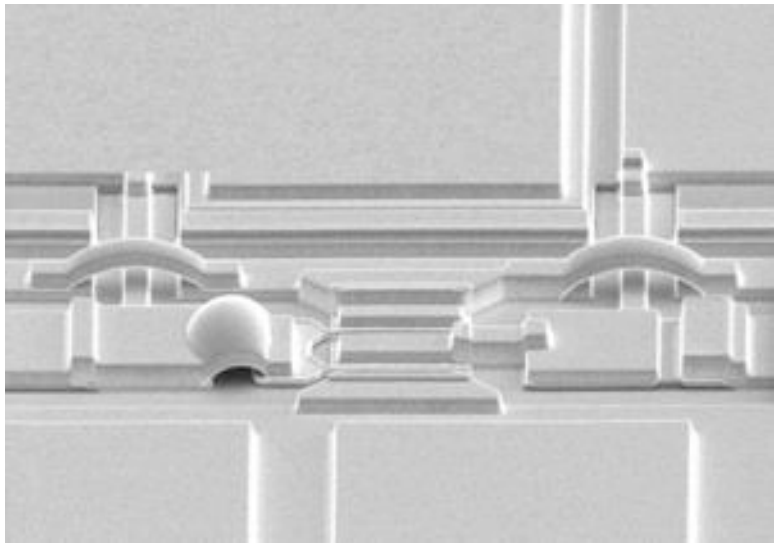
- 70 years of unmatched success and expansion into all aspects of the society
- The crucial theory: Boolean algebra [George Boole, 1854]
- The crucial theory-practice bridge: switching algebra [Claude Shannon, 1938]
- The crucial technological invention: the transistor [Shockley, Bardeen, and Brattain, Bell Labs 1947, Nobel Prize 1956] and the IC [Kilby, TI 1958, Nobel Prize 2000]
- What makes it going strong: semiconductor technology, VLSI, CAD, Internet, WEB, applications, algorithms, software, games, ...

"The first transistor ever assembled, invented in Bell Labs in 1947." Photo and text from Porticus.org, www.porticus.org/bell/belllabs_transistor.html. *(Follow that link to see more historical documents and images about Bell Labs and the transistor.)*

WE CAME LONG WAY SINCE THEN



SWITCHING FASTER AND FASTER



switches at 1THz (1000 GHz)

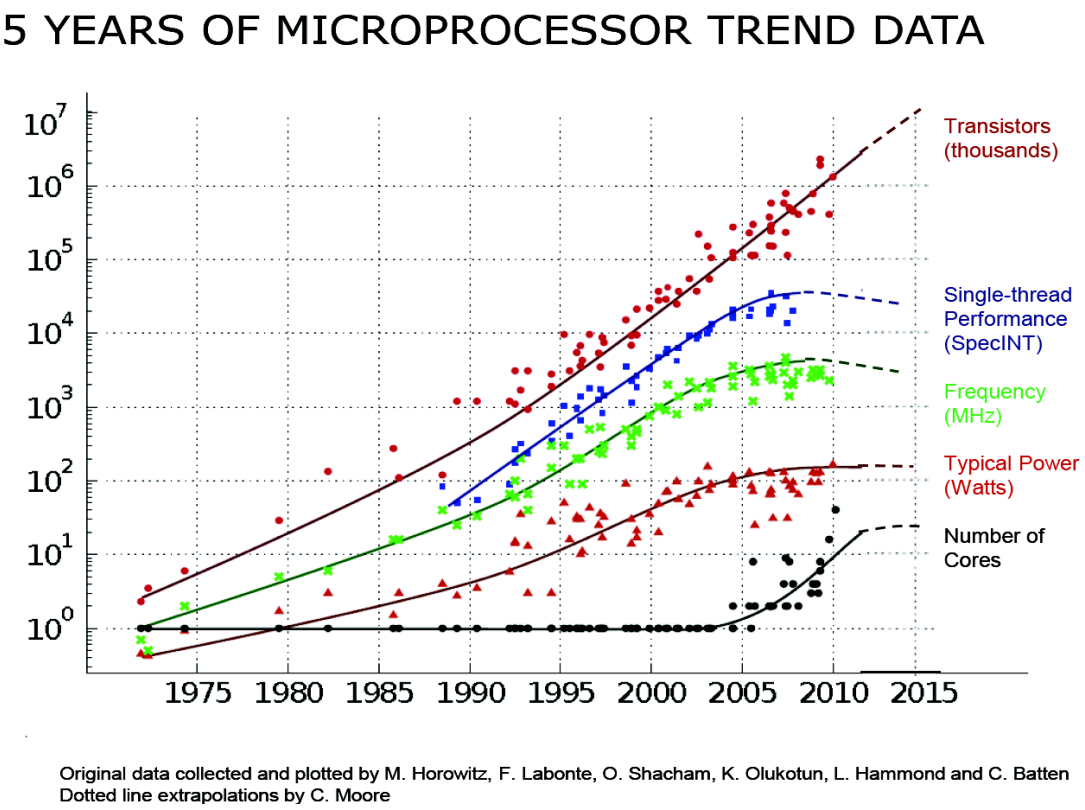
indium phosphide-based high electron mobility transistor

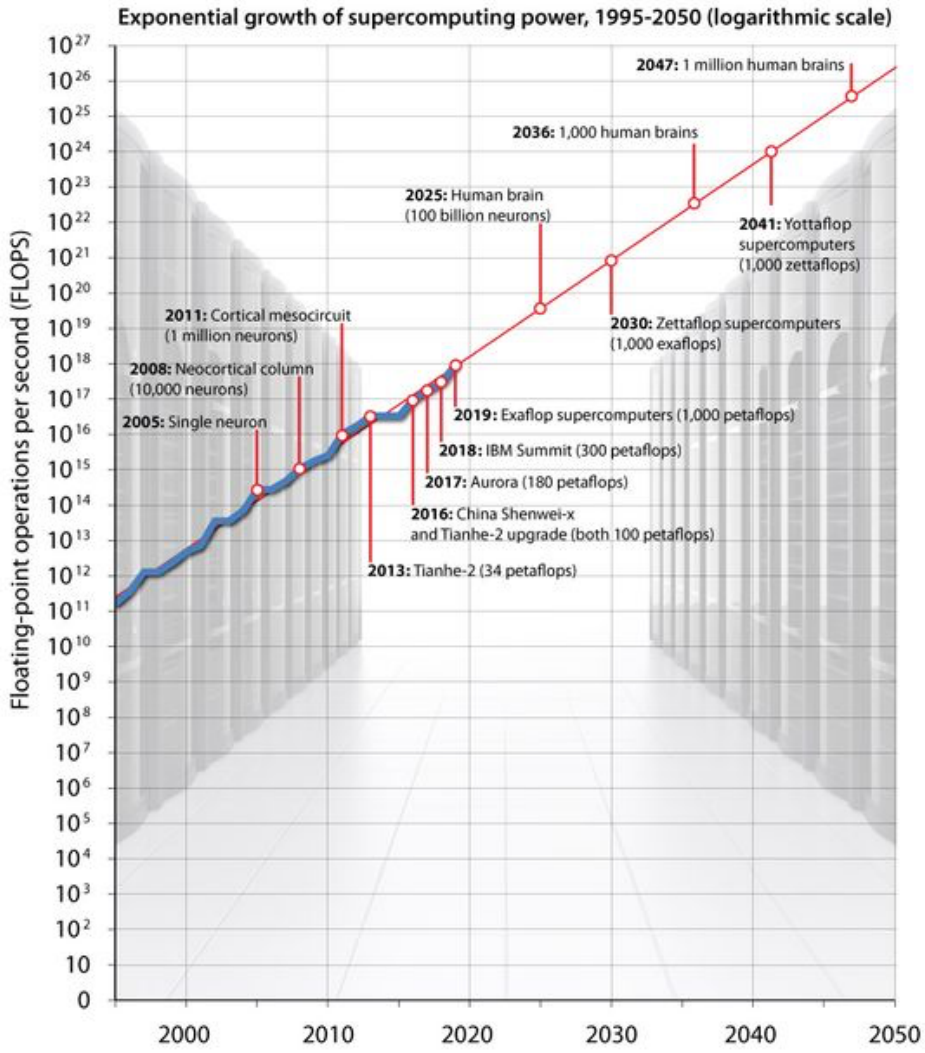
Northrop Grumman Corp. 2009

Source: Los Angeles Times, March 31, 2009

GREAT PROGRESS OF VLSI - END APPROACHING

Moore's Law: Transistors/inch^2 doubles every 18 months[Intel]




Exponential growth of supercomputing power, 1995-2050 (logarithmic scale)
Floating-point operations per second (FLOPS)
2047: 1 million human brains
2036: 1,000 human brains
2025: Human brain (100 billion neurons)
2041: Yottaflop supercomputers (1,000 zettaflops)
2030: Zettaflop supercomputers (1,000 exaflops)
2011: Cortical mesocircuit (1 million neurons)
2008: Neocortical column (10,000 neurons)
2005: Single neuron
2019: Exaflop supercomputers (1,000 petaflops)
2018: IBM Summit (300 petaflops)
2017: Aurora (180 petaflops)
2016: China Shenwei-x and Tianhe-2 upgrade (both 100 petaflops)
2013: Tianhe-2 (34 petaflops)
2000
2010
2020
2030
2040
2050
www.FutureTimeline.net