The Second Machine Age

Prof. Levy
Fromm Institute for Lifelong Learning
Spring Session 2018
The Second Machine Age

• The Second Machine Age (the book)
  • Chapter 3  **Moore’s Law**
    • Sustained exponential growth
The Second Machine Age

• Lecture 2 preview
  • History of computers – “the unprecedented technology”
  • Basis for computers – digital logic chips
  • How chips are made
  • Consequences of Moore’s Law
Background technology

• Vacuum tubes
• Transistors
• Integrated circuits (ICs)
• Logic gates & flip-flops
• Computer processors
Vacuum tube
1904-1907
Triode vacuum tube

Glass tube
Anode
Grid
Heated cathode
Heater
Eniac computer – 1943-1946
Transistor 1947-1954
transistor radio - 1954
Amateur Radio
1955
Preview of computer logic

• With tubes or transistors, we can make
  • Circuits that perform “logic” operations (AND, OR, NOT, ...)
  • Circuits that hold (temporarily store) a logic bit (TRUE, FALSE, or 0, 1)
  • And we can put them together into groups holding multiple bits (REGISTER)
  • Circuits that select one input signal from several possible inputs
  • Circuits that direct an output signal to one of several destinations
  • Circuits that generate a “clock” signal, to synchronize other circuits
Logic circuits
Computer logic

Output = \overline{ABC} + \overline{A}\overline{B}C + A\overline{B}\overline{C} + ABC
CPU Architecture

- CPU
  - I/O interface
  - ALU
  - Control unit
    - Program counter
  - Memory
8085 microprocessor - 1976
DEC “flip chip” module
Another DEC flip chip module (with ICs)
DEC flip chip modules in a frame (back-plane)
A wire-wrap back-plane
A wafer of integrated circuit (IC) chips
A “dual in-line package” container for a chip

DIP

Die
Bonding wire
Mold resin
Leadframe
Integrated circuit in a DIP
Complex chips in “quad flat-pack”
A chip in a QFP
Logic circuits

Equivalent electrical scheme of logic circuits

Buffer (P)

AND

OR

EXOR

NO

NAND

NOR

FLIP-FLOP
Computer logic

Output = \overline{ABC} + \overline{A}BC + A\overline{B}C + ABC
8085 microprocessor - 1976
Moore’s Law - 1965

• “The number of transistors on an integrated circuit chip doubles approximately every two years.”
Trends in computers driven by Moore’s Law

Price in dollars (log scale)

$ price

Mainframes

360

/81

Minicomputers

11/85 vx780

11/45 11/70 vx750

11/20 11/60 vx730

Workstations

11/05 11/23 LSI-11

Personal computers

PC XT AT clones clones clones clones clones

Servers

UNIX

Linux

Internet of Things

Netbooks and cell phones

Servers

Personal computers

Smartphones

Constant-price market

Constant compute power

year


year

processor chips
1971 – 2016

IBM PC
Apple II
Making integrated-circuit chips

• Design, fab, test, integrate

• Cost of a fab facility

• How many chips do you have to sell?
A complex, many-layer process

- Low-resistivity 3D connections
- Low thermal budget top layer
- Local interconnect Level
- High-quality top film
- Bottom MOS FET thermal stability
A complex, many-layer process

- Low-resistivity 3D connections
- Low thermal budget top layer
- Local interconnect Level
- High-quality top film
- Bottom MOS FET thermal stability
Consequences of Moore’s Law

• Digital things get cheaper (per computation)

• Digital replaces analog

• Complex digital things become affordable – such as PCs

• Digital logic chips lead to a communications revolution
Consequences: Digital replaces analog

- Cameras
- **Audio & video** recording
- Printing
- Feedback **control systems** (factory, automotive)
- **Computation** (instead of slide rules, logarithmic tables, ...)
- **Additive manufacturing** (3D printing)
- **Communications** (short, medium, and long-distance)
Consequences: a communications revolution

• Network speed (using fiber-optic cables)
• Internet routers
FIGURE 3.3 The Many Dimensions of Moore’s Law

- Supercomputer Speed (FLOPS)
- Supercomputer Energy Efficiency (FLOPS/watt)
- Residential Internet Download Speed (kilobytes/second)
- Microprocessor Transistors/Chip
- Hard Drive Cost Efficiency (gigabytes/dollar)

Logarithmic Scale

1,000,000,000,000
1,000,000,000,000
1,000,000,000
1,000,000
1,000
1

YEAR
Consequences: Storage gets denser & cheaper

• Hard disk drives

• Solid-state disks (SSD)
Other questions to be answered

• What is software?
  • Why is it still the main driver of AND obstacle to future improvements?

• What is the software underlying “A.I.”?
  • What is machine learning?

• How do AI and machine learning underpin autonomous vehicles?
The Second Machine Age (this course)

• Supplementary reading and videos
  • “How Computers Work” video series
    • https://www.youtube.com/watch?v=OAx_6-wdslM&index=1&list=PLzdOnOPl1iJNcsRwJhvKsE01tJqjIqWbN-
  • “How the Internet Works” video series
    • https://www.youtube.com/watch?v=Dxcc6ycZ73M&index=1&list=PLzdOnOPl1iJNfMRZm5DDxco3UdsFegvuB7