Lecture 1: A Brief History of Computers and Processors

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Outline

- Early computers
- Mechanical age
- Electrical age
- Electronic age
  - Transistors
  - Integrated circuits
- Evolution of x86 and ARM processors

Before Using Machines

- Early computers were *people*
  - It was a job title
  - First use of the word "computer" in 1613
- Perform repetitive calculations such as multiplications
  - Error prone

Old Aiding Devices

- Abacus
- The period 2700–2300 BC saw the first appearance of the Sumerian abacus
- Aid an individual in performing basic mathematical calculations

Old Aiding Devices

- Napier's Bones
  - Invented by John Napier in 1614
- Allowed the operator to **multiply**, **divide** and **calculate square** and **cube roots** by moving the rods around and placing them in specially constructed boards.

John Napier

Napier's Bones

Old Aiding Devices

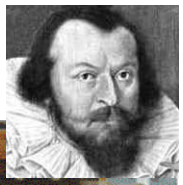
- Slide Rule
  - Invented by William Oughtred in 1622.
- Is based on Napier's ideas about **logarithms**.
- Used primarily for
  - **multiplication**
  - **division**
  - **roots**
  - **logarithms**
  - **Trigonometry**
- Not normally used for addition or subtraction.

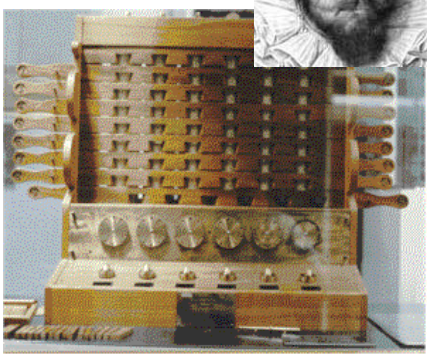
William Oughtred

Slide Rule

The Mechanical Age

- The calculating clock
  - So called by the German inventor Wilhelm Schickard in 1623
- The first gear-driven calculating machine to actually be built
  - Non-programmable
  - Decimal integers





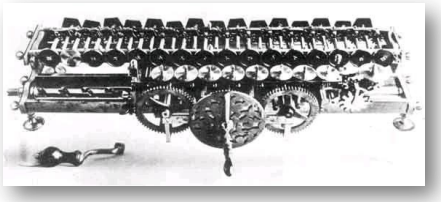
The Mechanical Age

- 1642, Pascal's adding machine (Pascaline)
  - Made as an aid for his father (tax collector)
- Calculator with gears and wheels
  - Each gear contained 10 teeth
  - When moved one complete revolution, a second gear advances one place.
- Expensive

The Mechanical Age

- Stepped Reckoner
  - Invented by Gottfried Wilhelm Leibniz in 1672.
  - The first machine that can add, subtract, multiply, and divide automatically.

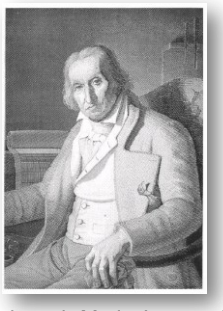
Gottfried Wilhelm Leibniz



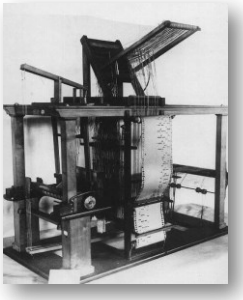
Stepped Reckoner

The Mechanical Age

- Jacquard Loom
  - The Jacquard loom is a mechanical loom, invented by Joseph-Marie Jacquard in 1881.
  - It an automatic loom controlled by punched cards.



Joseph-Marie Jacquard



Jacquard Loom

The Mechanical Age

- Arithmometer
  - A mechanical calculator invented by Thomas de Colmar in 1820.
  - The first reliable, useful and commercially successful calculating machine.
  - The machine could perform the four basic mathematic functions.

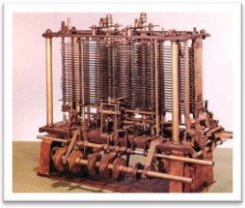
Thomas de Colmar

Arithmometer

The Mechanical Age

- Difference Engine and Analytical Engine
  - Invented by Charles Babbage in 1822 and 1834
  - It is the first mechanical computer
  - Designed to tabulate polynomial functions and generate navigational tables
  - Used punched cards
  - Stored 1000 20-digit decimal numbers
  - large as a house and powered by 6 steam engines
- Aided by Ada Byron, Countess of Lovelace
  - She suggested him to use binary numbers
  - She is the first computer programmer
    - For the analytical engine

Charles Babbage

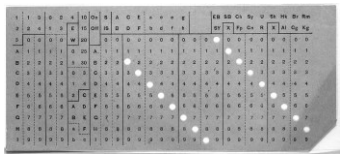


Difference Engine

Analytical Engine

The Electrical Age
Electromechanical Machines

- 1800s, The advent of electric motor
- In 1889, Herman Hollerith developed the punched card for storing data.
- Also developed mechanical machine that counted, sorted, and collated information stored on punched cards
- Hollerith commissioned to use system to store and tabulate 1890 census information of US
- In 1896 Hollerith formed Tabulating Machine Company
  - Later merged to IBM



The Electrical Age

- Z1: The first programmable computer created by Konrad Zuse in Germany from 1936 to 1938.
- 1941, Z3 calculating computer by Konrad Zuse
- World's first fully electromechanical programmable computer
- Application in aircraft and missile design during WWII in Germany
- Z3 a relay logic machine clocked at 5.33 Hz

Z1

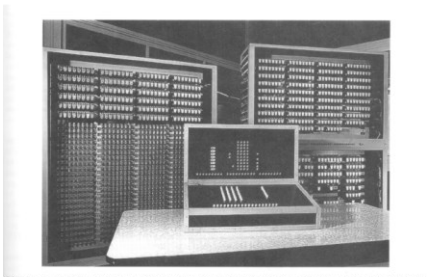
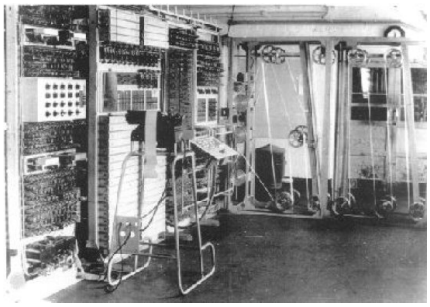


FIGURE 1–1 The Z3 computer developed by Konrad Zuse used a 5.33 Hertz clocking frequency. (Photo courtesy of Horst Zuse, the son of Konrad.)

The Electrical Age

- 1943, British Colossus
- Invented by Alan Turing
- Broke secret German military codes (Generated by mechanical Enigma machine)
  - could not solve other problems
- First to use vacuum tubes
- Not programmable



1st Gen Computers

- Used
  - vacuum tubes for circuitry
  - magnetic drums for memory
- Were often enormous, taking up entire rooms.
- Very expensive to operate
- Using a great deal of electricity, generated a lot of heat,
  - which was often the cause of malfunctions.
- Relied on machine language
  - could only solve one problem at a time
- Input was based on punched cards and paper tape and output was displayed on printouts.

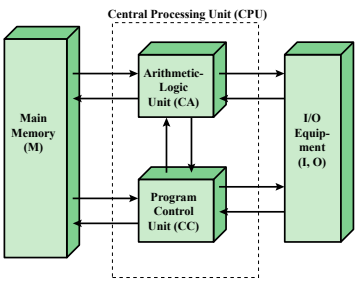
Vacuum tube

The Electrical Age

- 1946, ENIAC (Electronic Numerical Integrator and Computer), University of Pennsylvania
- 17,000 vacuum tubes, 500 miles of wires
- Weighted over 30 tons
- 100,000 operations per second
- 140 kW power consumption
- Decimal rather than binary machine
- *Programmed by rewiring its circuits*

EDVAC (Electronic Discrete Variable Computer)

- First publication of the idea was in 1945
- Stored program concept
  - Attributed to ENIAC designers, most notably the mathematician John von Neumann
  - Program represented in a form suitable for storing in memory alongside the data
- IAS computer
  - Princeton Institute for Advanced Studies
  - Prototype of all subsequent general-purpose computers
  - Completed in 1952

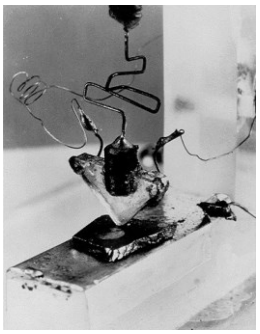


The Electrical Age (continued)

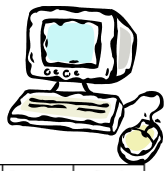
- 1951 - UNIVAC - UNIVersal Automatic Computer
  - the first commercial, mass produced computer
  - Performs add in 282 microseconds
- Once such became available, assembly language was used to simplify entering binary code.

Electronic Age
2nd Gen: Transistors

- Smaller
  - One transistor replaced 40 vacuum tubes
- Cheaper
- Dissipates less heat than a vacuum tube
- More reliable
- Is a solid state device made from silicon
- Was invented at Bell Labs in 1947
- It was not until the late 1950's that fully transistorized computers were commercially available
  - Moved to assembly language
  - stored their instructions in their memory



Example: Members of the IBM 700/7000 Series



Model Number	First Delivery	CPU Technology	Memory Technology	Cycle Time (µs)	Memory Size (K)	Number of Opcodes	Number of Index Registers	Hardwired Floating-Point	I/O Overlap (Channels)	Instruction Fetch Overlap	Speed (relative to 701)
701	1952	Vacuum tubes	Electrostatic tubes	30	2–4	24	0	no	no	no	1
704	1955	Vacuum tubes	Core	12	4–32	80	3	yes	no	no	2.5
709	1958	Vacuum tubes	Core	12	32	140	3	yes	yes	no	4
7090	1960	Transistor	Core	2.18	32	169	3	yes	yes	no	25
7094 I	1962	Transistor	Core	2	32	185	7	yes (double precision)	yes	yes	30
7094 II	1964	Transistor	Core	1.4	32	185	7	yes (double precision)	yes	yes	50

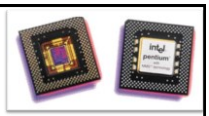
Electronic Age
3rd Gen: Integrated Circuits

- 1958 – the invention of the integrated circuit
- *IC*, *microcircuit*, *microchip*, *silicon chip*, or *chip*
- Integrated Circuit is a *miniaturized electronic circuit*
  - Consisting mainly of *semiconductor devices*, as well as *passive components*
  - Is manufactured in the surface of a *thin substrate of semiconductor* material
- The two most important members of the third generation were the IBM System/360 and the DEC PDP-8
  - Users interacted with 3rd gen computers through keyboards and monitors
  - Interfaced with an operating system
    - which allowed the device to run many different applications at one time with a central program that monitored the memory.

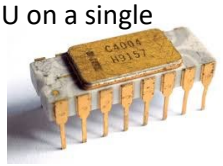
Technology Advance and the Moore's Law

- LSI: Large Scale Integration
  - More than 1000 components can be placed on a single integrated circuit chip
- VLSI: Very Large Scale Integration
  - 10,000 components per chip
- ULSI: Ultra Large Scale Integration
  - Millions of components per chip
- …

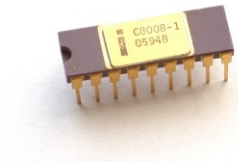
Electronic Age
4th Gen: Microprocessors



- 1971, Intel 4004 and 4040
  - First chip to contain all of the components of a CPU on a single chip (birth of microprocessors)
  - 4-bit microprocessors
  - addressed 4096 (4-bit) memory locations
  - 45 instructions
  - many calculators and low-end applications such as microwave ovens may still use 4-bit microprocessors



- 1972, Intel 8008
  - First 8-bit microprocessor
  - addressed 16K memory locations
  - 48 instructions
  - 50,000 instructions per second



Microprocessors

- 1973, Intel 8080
  - First general purpose microprocessor
  - addressed *64K memory* locations
  - *500,000 instructions per second* (2 μs per instr.)
- 1974, Motorola 6800
- 1974, The first personal computer
- 1977, Intel 8085
  - *769,230 instructions per second* (1.3 μs per instr.)
  - internal clock generator and system controller

Early 8-bit Microprocessors

Manufacturer	*Part Number*
Fairchild	F-8
Intel	8080
MOS Technology	6502
Motorola	MC6800
National Semiconductor	IMP-8
Rockwell International	PPS-8
Zilog	Z-8

Evolution of Intel Microprocessors

	4004	8008	8080	8086	8088
Introduced	1971	1972	1974	1978	1979
Clock speeds	108 kHz	108 kHz	2 MHz	5 MHz, 8 MHz, 10 MHz	5 MHz, 8 MHz
Bus width	4 bits	8 bits	8 bits	16 bits	8 bits
Number of transistors	2,300	3,500	6,000	29,000	29,000
Feature size (μm)	10		6	3	6
Addressable memory	640 Bytes	16 KB	64 KB	1 MB	1 MB

a. 1970s Processors

	80286	386TM DX	386TM SX	486TM DX CPU
Introduced	1982	1985	1988	1989
Clock speeds	6 MHz - 12.5 MHz	16 MHz - 33 MHz	16 MHz - 33 MHz	25 MHz - 50 MHz
Bus width	16 bits	32 bits	16 bits	32 bits
Number of transistors	134,000	275,000	275,000	1.2 million
Feature size (μm)	1.5	1	1	0.8 - 1
Addressable memory	16 MB	4 GB	16 MB	4 GB
Virtual memory	1 GB	64 TB	64 TB	64 TB
Cache	—	—	—	8 kB

b. 1980s Processors

Evolution of Intel Microprocessors

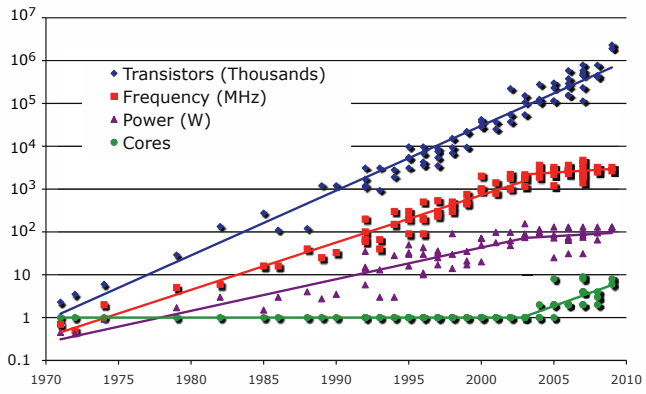
	486TM SX	Pentium	Pentium Pro	Pentium II
Introduced	1991	1993	1995	1997
Clock speeds	16 MHz - 33 MHz	60 MHz - 166 MHz,	150 MHz - 200 MHz	200 MHz - 300 MHz
Bus width	32 bits	32 bits	64 bits	64 bits
Number of transistors	1.185 million	3.1 million	5.5 million	7.5 million
Feature size (μm)	1	0.8	0.6	0.35
Addressable memory	4 GB	4 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	8 kB	8 kB	512 kB L1 and 1 MB L2	512 kB L2

c. 1990s Processors

	Pentium III	Pentium 4	Core 2 Duo	Core i7 EE 990
Introduced	1999	2000	2006	2011
Clock speeds	450 - 660 MHz	1.3 - 1.8 GHz	1.06 - 1.2 GHz	3.5 GHz
Bus width	64 bits	64 bits	64 bits	64 bits
Number of transistors	9.5 million	42 million	167 million	1170 million
Feature size (nm)	250	180	65	32
Addressable memory	64 GB	64 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	512 kB L2	256 kB L2	2 MB L2	1.5 MB L2/12 MB L3

d. Recent Processors

Microprocessor Trends



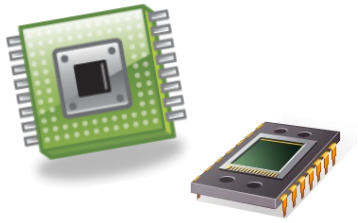
Overview of x86 and ARM Processors

x86

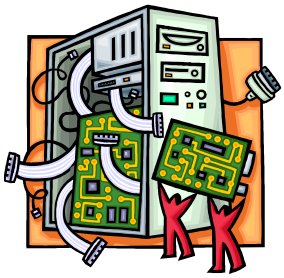
- Results of decades of design effort on complex instruction set computers (CISCs)
- Excellent example of CISC design
- Incorporates the sophisticated design principles once found only on mainframes and supercomputers

ARM

- An alternative approach to processor design is the reduced instruction set computer (RISC)
- Used in a wide variety of embedded systems
- One of the most powerful and best designed RISC based systems on the market

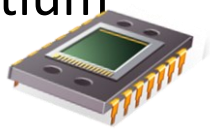


x86 Evolution



- 8080
  - First general purpose microprocessor
  - 8-bit machine with an 8-bit data path to memory
  - Used in the first personal computer (Altair)
- 8086
  - 16-bit machine
  - Used an instruction cache, or queue
  - First appearance of the x86 architecture
- 8088
  - used in IBM's first personal computer
- 80286
  - Enabled addressing a 16-MByte memory instead of just 1 MByte
- 80386
  - Intel's first 32-bit machine
  - First Intel processor to support multitasking
- 80486
  - More sophisticated cache technology and instruction pipelining
  - Built-in math coprocessor

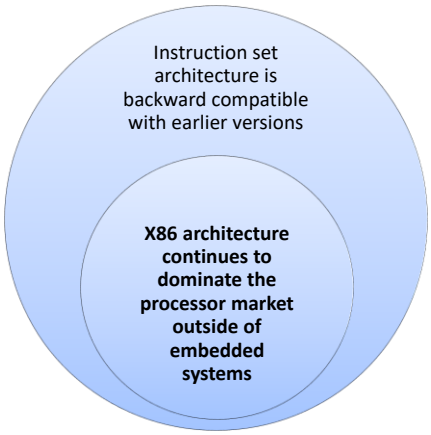
x86 Evolution - Pentium



Pentium	Pentium Pro	Pentium II	Pentium III	Pentium 4
• Superscalar • Multiple instructions executed in parallel	• Increased superscalar organization • Aggressive register renaming • Branch prediction • Data flow analysis • Speculative execution	• MMX technology • Designed specifically to process video, audio, and graphics data	• Additional floating-point instructions to support 3D graphics software	• Includes additional floating-point and other enhancements for multimedia

x86 Evolution (continued)

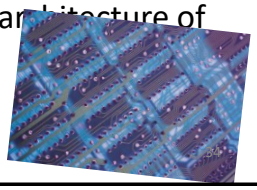
- Core
  - First Intel x86 microprocessor with a dual core, referring to the implementation of two processors on a single chip
- Core 2
  - Extends the architecture to 64 bits
  - Recent Core offerings have up to 10 processors per chip
- …



Acorn RISC Machine (ARM)

- Family of RISC-based microprocessors and microcontrollers
- Designs microprocessor and multicore architectures and licenses them to manufacturers
- Chips are high-speed processors that are known for their small die size and low power requirements

- Widely used in PDAs and other handheld devices
- Chips are the processors in iPod and iPhone devices
- Most widely used embedded processor architecture
- Most widely used processor architecture of any kind



ARM Evolution

Family	Notable Features	Cache	Typical MIPS @ MHz
ARM1	32-bit RISC	None	
ARM2	Multiply and swap instructions; Integrated memory management unit, graphics and I/O processor	None	7 MIPS @ 12 MHz
ARM3	First use of processor cache	4 KB unified	12 MIPS @ 25 MHz
ARM6	First to support 32-bit addresses; floating-point unit	4 KB unified	28 MIPS @ 33 MHz
ARM7	Integrated SoC	8 KB unified	60 MIPS @ 60 MHz
ARM8	5-stage pipeline; static branch prediction	8 KB unified	84 MIPS @ 72 MHz
ARM9		16 KB/16 KB	300 MIPS @ 300 MHz
ARM9E	Enhanced DSP instructions	16 KB/16 KB	220 MIPS @ 200 MHz
ARM10E	6-stage pipeline	32 KB/32 KB	
ARM11	9-stage pipeline	Variable	740 MIPS @ 665 MHz
Cortex	13-stage superscalar pipeline	Variable	2000 MIPS @ 1 GHz
XScale	Applications processor; 7-stage pipeline	32 KB/32 KB L1 512 KB L2	1000 MIPS @ 1.25 GHz

DSP = digital signal processor SoC = system on a chip

ARM Design Categories

- ARM processors are designed to meet the needs of three system categories:

Secure applications
- Smart cards, SIM cards, and payment terminals

Embedded real-time systems
- Systems for storage, automotive body and power-train, industrial, and networking applications

Application platforms
- Devices running open operating systems including Linux, Palm OS, Symbian OS, and Windows CE in wireless, consumer entertainment and digital imaging applications

Todays Computers: Embedded, Pervasive, Wearable, …