

Early and Modern Digital Computers

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Memory-Stored Control

- The control sequence points are replaced by *instructions* (“orders”), their digital encodings
- von Neumann: 12 decimal digits (~40 bits).
Modern MIPS architecture: 32 bits per instruction
- An “order” (a *machine language instruction*) indicates the operation, source register, a target register; it may modify a special register for control, the *program counter (PC)*
- The “orders” are stored in the memory!
- The program (a sequence of “orders”/instructions) is loaded into the memory

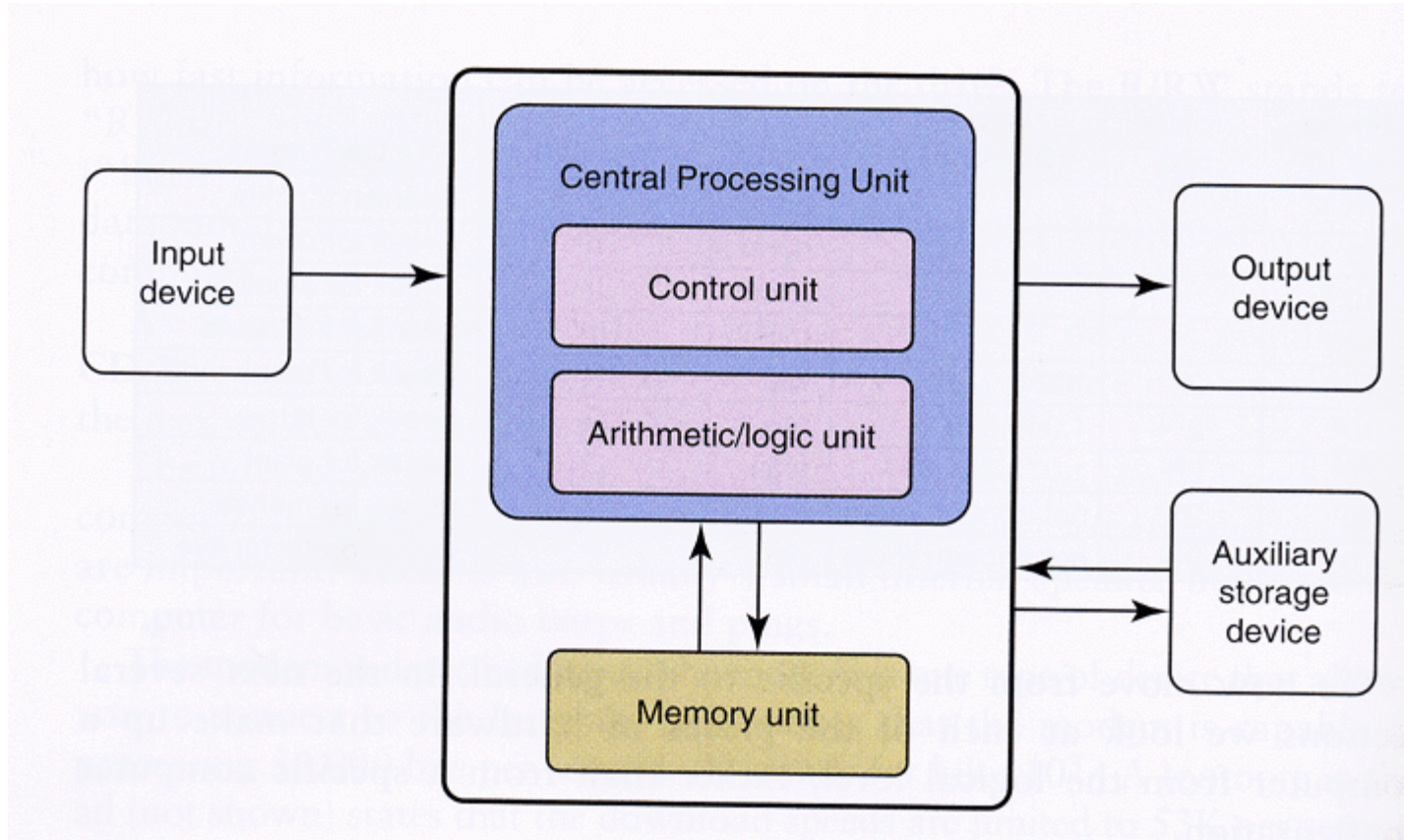
Types of Memory (modern)

- ROM: Read-Only Memory
- RAM: Random Access Memory
 - SRAM: *Static random access memory* retains its contents as long as power remains applied
 - DRAM: *Dynamic random access memory* stores each bit of data in a separate capacitor within an integrated circuit. Capacitors leak charge, so the capacitor charge is refreshed periodically.

Kilo, Mega, Giga...

Power of 10	Power of 2	Value of Power of 2	Prefix	Abbreviation	Derivation
10^3	2^{10}	1,024	kilo	K	Greek for thousandth
10^6	2^{20}	1,048,576	mega	M	Greek for large
10^9	2^{30}	1,073,741,824	giga	G	Greek for giant
10^{12}	2^{40}	-	tera	T	Greek for monster
10^{15}	2^{50}	-	peta	P	Greek prefix for five

von Neumann Architecture (reminder)



The Fetch-Execute Cycle

- Fetch the next instruction
- Decode the instruction
- Get data if needed
- Execute the instruction

Mixed Forms of Control

- A plugged control scheme may load the program into the memory and designate the memory-stored control as its successor!
- This is similar to BIOS starting from ROM and booting the computer by loading other components of the operating system into the memory and transferring control to them

Mixed Types of Computers

- Part of the machine is analog, part is digital, and they communicate with each other
- This approach involves analog-to-digital and digital-to-analog signal transformation

Mixed Representations of Numbers

- Pulse Density Modulation (PDM): The average density of the pulse sequence is the number represented. Problem: Low precision



Precision of Analog and Digital Computers

- Analog:
 - von Neumann (1956): 10^{-5} , i.e. ~ 17 bits
 - Hillis (1998): fewer than 30 bits
- Digital: Any desired finite precision!
- Why do we need high precision? Because round-off errors accumulate over long (often iterative) series of operations. Worse yet, small errors may be arithmetically amplified by subsequent operations!

Logical Operations and Brain

- “sense coincidences”: And
- “combine stimuli”: Or
- “sense anti-coincidences”: And + Not
- “regenerate pulses”: The Clock

Speed

- von Neumann (1956): 10^6 operations per second, i.e., 1 MHz
- AMD Opteron 2224SE released Aug. 5, 2007: 3.2 GHz

Memory Hierarchy

- Users want large and fast memories!

2004

SRAM access times are .5 – 5ns at cost of \$4000 to \$10,000 per GB.

DRAM access times are 50-70ns at cost of \$100 to \$200 per GB.

Disk access times are 5 to 20 million ns at cost of \$.50 to \$2 per GB.

- Try and give it to them anyway
 - build a memory hierarchy

