

What is Computing?

Scientific Computing

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Summer 2023

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2. Computer Hardware
3. Computer Software

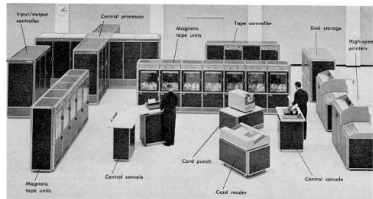
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What is a Computer?



A "computer" is anything that executes a set of defined instructions.

- ▶ We will mainly talk about computers that use electrical circuits.
- ▶ We can assume instructions are executed one at a time in order.
- ▶ In the common sense of the word, we will be talking about computers like your laptop or desktop computer (or also your phone).



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Operating Systems

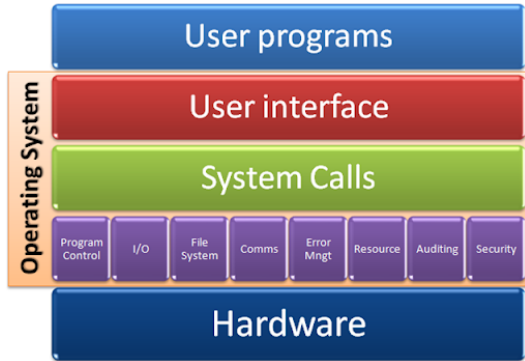
Most computers we interact with have a special set of instructions call an operating system that manage a lot of the tedious task of running the computer.

- ▶ Manages your internet connection
- ▶ Manages your screen display
- ▶ Manages your files and storage

Operating systems also provide an easy way to run our own instructions to do cool stuff along with other features.

- ▶ I can run software other people wrote, like a web browser or games.
- ▶ I can write my own code to run on the computer to do my research stuff.

Operating Systems



Mac OS



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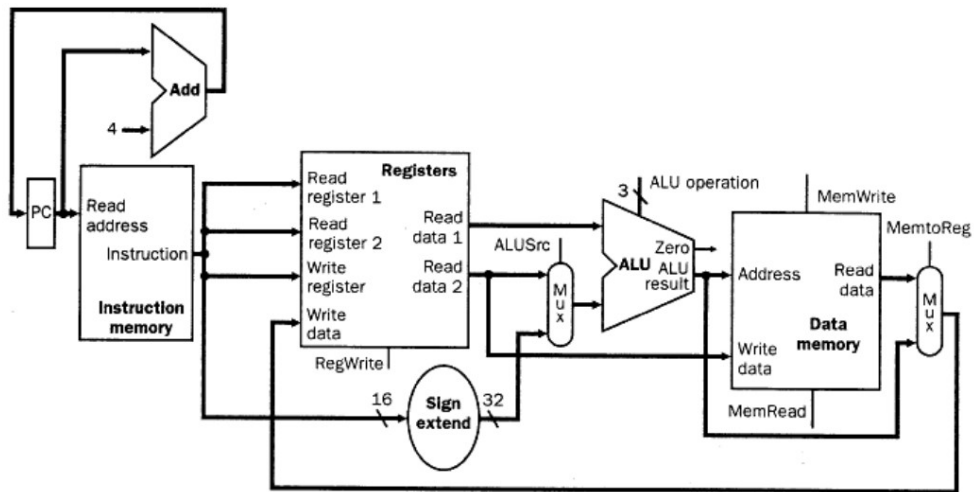
3. Computer Software

Lowest Level of a Computer

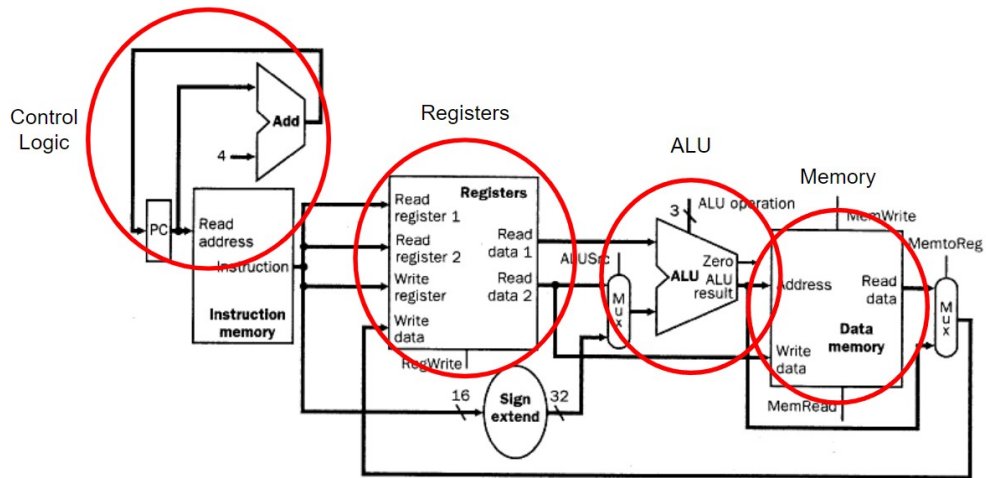
In the lowest level of hardware, there are several components:

- ▶ **Clock:** Keep a constant time, one tick every x seconds
- ▶ **Registers:** Where data is stored while working with it
- ▶ **Arithmetic Logic Unit (ALU):** Does the actual computations
 - ▶ Add / subtract two numbers, compare two numbers, execute logic functions (AND, OR, INVERSE, XOR)
 - ▶ Modern computers have cool features built-in like multiply, divide, multiply-add, decimal math, etc...
- ▶ **Control Logic:** Tells the computer what to do next
 - ▶ Keeps track of current instruction and next instruction
 - ▶ Can jump to different instructions and save current location to jump back to later
- ▶ **Memory:** Where data is stored while it's waiting to be worked on
 - ▶ Temporary - gets erased when you turn off the computer
- ▶ **Storage (Optional):** Where data is stored in the long-term
 - ▶ Permanent - doesn't get erased when you turn off the computer

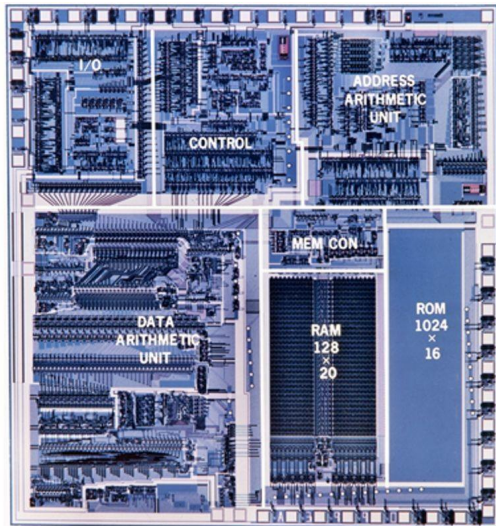
Lowest Level of a Computer



Lowest Level of a Computer



Lowest Level of a Computer

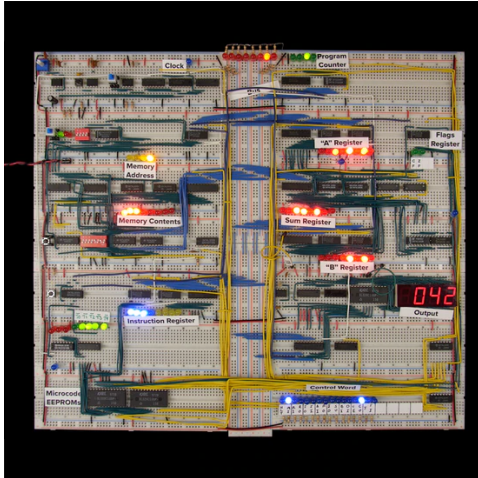


These elements usually make up your computer's central processing unit, or CPU. In reality, your computer can have

more than one copy of a CPU "core" to do different things simultaneously, making it faster to compute overall. Your computer

also has a bunch of extra hardware to handle power, graphics, storage, and interfacing with other things like your mouse, keyboard, screen, camera, USB port, wifi chip, ...

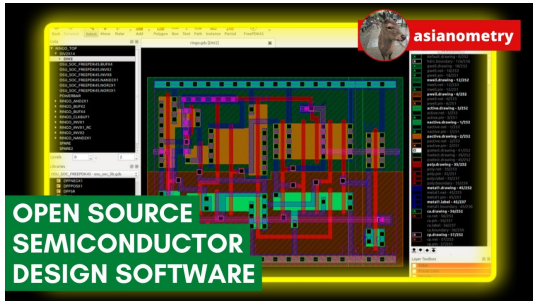
Making a Computer



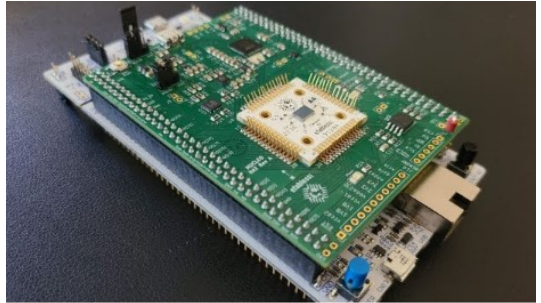
You (yes you!) can make your own computer very easily from scratch. In fact RISC-V and other open-source hardware tools are commonly used by both students and professionals to do research and develop new hardware.

”Build an 8-bit computer from scratch”

Making a Computer



"The Promise of Open Source Semiconductor Design Tools"



Example of a fabricated chip using open-source tools and fabrication technology

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Computer Instructions

At the lowest level, each CPU hardware design has a set of basic instructions called an Instruction Set Architecture or **ISA**.

- ▶ Intel has an ISA called x86
- ▶ Many phones and Apple computers use an ISA called ARM
- ▶ Arduinos use an ISA called AVR

An ISA is an outline of the set of instructions that a CPU can perform.

- ▶ Add two numbers
- ▶ Move this number from location A to location B
- ▶ Compare two numbers or compare a number to zero
- ▶ Jump to this location in the code
- ▶ Run this block of code and come back when done
- ▶ Load and store this number in this location of memory

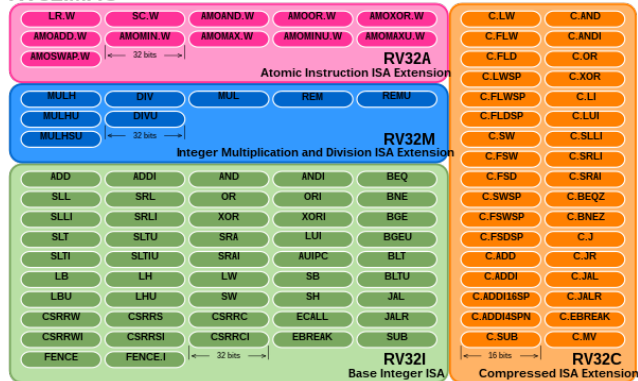
Computer Instructions

Category	Example Instruction		Meaning
Arithmetic	add	\$t0, \$t1, \$t2	$\$t0 = \$t1 + \$t2$
	sub	\$t0, \$t1, \$t2	$\$t0 = \$t1 - \$t2$
	addi	\$t0, \$t1, 100	$\$t0 = \$t1 + 100$
	mul	\$t0, \$t1, \$t2	$\$t0 = \$t1 \times \$t2$
	div	\$t0, \$t1, \$t2	$\$t0 = \$t1 / \$t2$
Logical	and	\$t0, \$t1, \$t2	$\$t0 = \$t1 \& \$t2$ (Logical AND)
	or	\$t0, \$t1, \$t2	$\$t0 = \$t1 \$t2$ (Logical OR)
	sll	\$t0, \$t1, \$t2	$\$t0 = \$t1 \ll \$t2$ (Shift Left Logical)
	srl	\$t0, \$t1, \$t2	$\$t0 = \$t1 \gg \$t2$ (Shift Right Logical)
Register Setting	move	\$t0, \$t1	$\$t0 = \$t1$
	li	\$t0, 100	$\$t0 = 100$
Data Transfer	lw	\$t0, 100(\$t1)	$\$t0 = \text{Mem}[100 + \$t1]$ 4 bytes
	lb	\$t0, 100(\$t1)	$\$t0 = \text{Mem}[100 + \$t1]$ 1 byte
	sw	\$t0, 100(\$t1)	$\text{Mem}[100 + \$t1] = \$t0$ 4 bytes
	sb	\$t0, 100(\$t1)	$\text{Mem}[100 + \$t1] = \$t0$ 1 byte
Branch	beq	\$t0, \$t1, Label	if ($\$t0 = \$t1$) go to Label
	bne	\$t0, \$t1, Label	if ($\$t0 \neq \$t1$) go to Label
	bge	\$t0, \$t1, Label	if ($\$t0 \geq \$t1$) go to Label
	bgt	\$t0, \$t1, Label	if ($\$t0 > \$t1$) go to Label
	ble	\$t0, \$t1, Label	if ($\$t0 \leq \$t1$) go to Label
	blt	\$t0, \$t1, Label	if ($\$t0 < \$t1$) go to Label
Set	slt	\$t0, \$t1, \$t2	if ($\$t1 < \$t2$) then $\$t0 = 1$ else $\$t0 = 0$
	slti	\$t0, \$t1, 100	if ($\$t1 < 100$) then $\$t0 = 1$ else $\$t0 = 0$
Jump	j	Label	go to Label
	jr	\$ra	go to address in \$ra
	jal	Label	$\$ra = PC + 4$; go to Label

An example of a simple ISA

Computer Instructions

RV32IMAC



An example of a RISC-V ISA

Programming Languages

Programmers want a more expressive way to write programs for their computers with more features rather than just the assembly language

They designed higher level languages that can be translated, aka compiled, into lower level code (ex. an ISA)

These higher level languages have more useful features and better language and syntax

- ▶ Standard libraries for things like math, file reading, networking, graphics, user interfaces
- ▶ Memory management
- ▶ Concurrency and parallelism

Programming Languages

You can now build higher level functionality like a file system, a desktop user interface, user management, networking (wifi and ethernet), a way to run other applications, and a web browser

All of a sudden you have an operating system

- ▶ That previous point kinda sounds like Chrome OS on your Chromebook
- ▶ Windows, Mac, Linux

Programming Languages

Programs and Applications



Higher Level Language (ex. C / C++)

```
1 | #include <stdio.h>
2 |
3 | int add( int num1, int num2 ) {
4 |     num1 = num1 + num2;
5 |     return num1;
6 | }
7 |
8 | int main(int argc, char **argv)
9 | {
10 |     printf("Result = %d\n", add(2,5));
11 |     return 0;
12 | }
```

Assembly Instructions

```
loop: lw  $t3, 0($t0)
      lw  $t4, 4($t0)
      add $t2, $t3, $t4
      sw  $t2, 8($t0)
      addi $t0, $t0, 4
      addi $t1, $t1, -1
      bgtz $t1, loop
```

Running On Hardware



Example of abstraction for software and hardware layers