Parallel Programming: Moore's Law and Multicore

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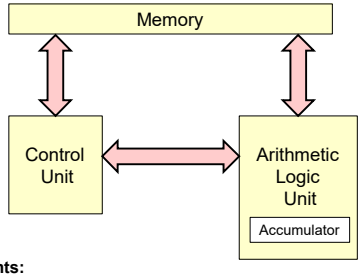
Von Neumann Architecture: Basically the fundamental pieces of a CPU have not changed since the 1960s



Other elements:

- **Clock**
- Registers
- Program counter
- Stack pointer

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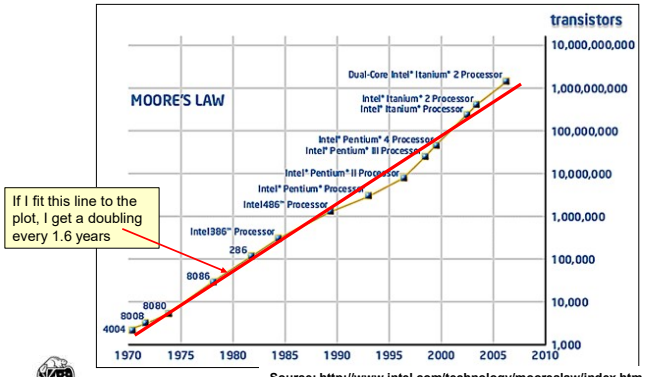
Increasing Transistor Density -- Moore's Law

"Transistor density doubles every 1.5 years."

Note: Log scale!



If I fit this line to the plot, I get a doubling every 1.6 years

Source: http://www.intel.com/technology/mooreslaw/index.htm

Oftentimes people have (*incorrectly*) equivalenced this to: "Clock speed doubles every 1.5 years."

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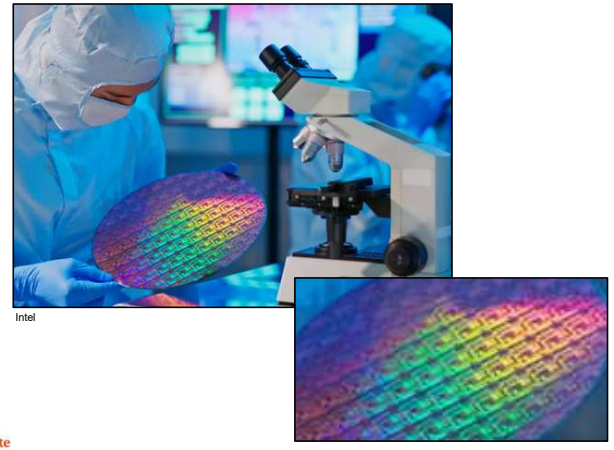
Increasing Transistor Density – How Many Working Chips Can You fit on a Silicon Wafer?



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Fabrication Process Size vs. Year

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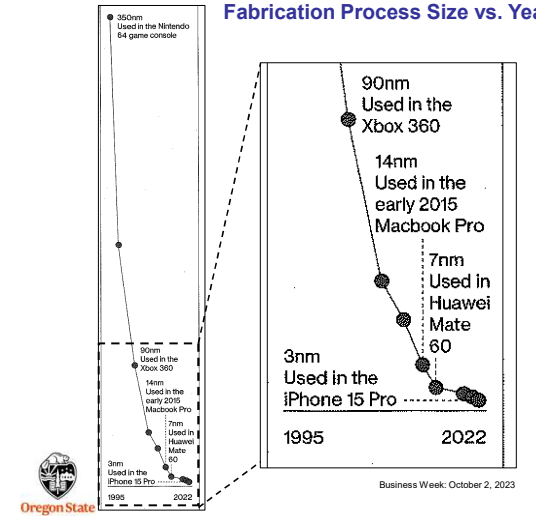

Business Week: October 2, 2023

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Increasing Clock Speed?

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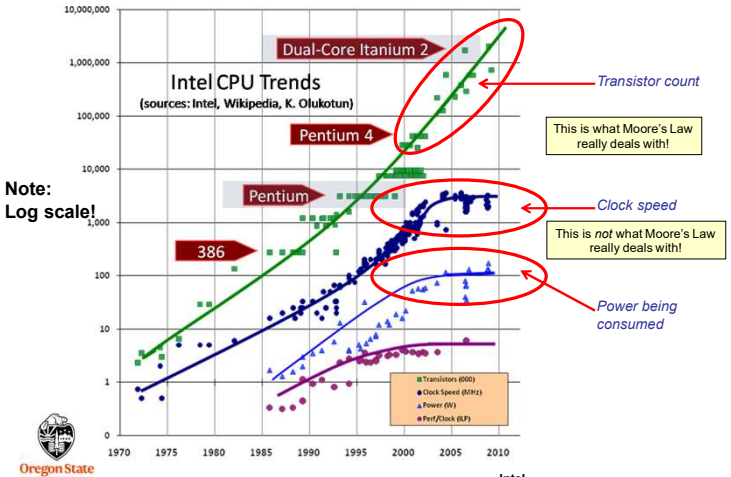

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Increasing Clock Speed?

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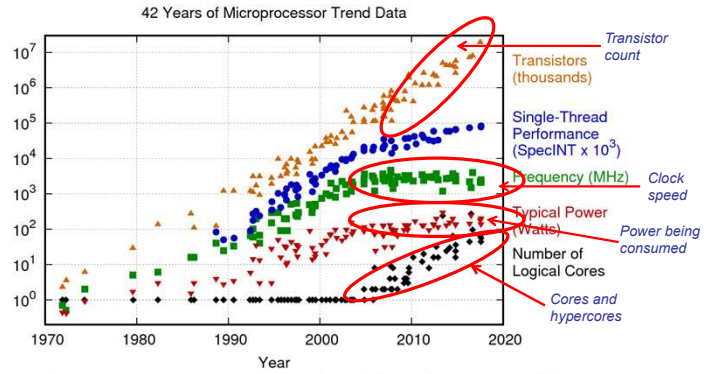

Source: Karl Rupp

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Moore's Law

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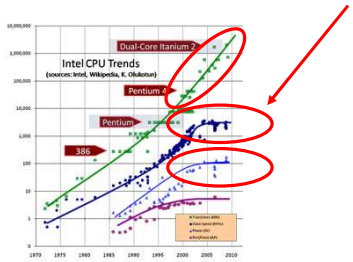
- Fabrication process size ("gate pitch") has fallen from 65 nm, to 45 nm, to 32 nm, to 22 nm, to 16 nm, to 11 nm, to 8 nm. This translates to more transistors on the same size die.
- From 1986 to 2002, processor performance increased an average of 52%/year, but then virtually plateaued.



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Clock Speed and Power Consumption

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1981	IBM PC	5 MHz
1995	Pentium	100 MHz
2002	Pentium 4	3000 MHz (3 GHz)
2007		3800 MHz (3.8 GHz)
2009		4000 MHz (4.0 GHz)

Clock speed has hit a plateau, largely because of power consumption and power dissipation.

$$PowerConsumption \propto ClockSpeed^2$$

is-proportional-to

Yikes!

Once consumed, that power becomes *heat*, which much be *dissipated* somehow. In general, compute systems can remove around 150 $^{watts}/_{cm^2}$ without resorting to exotic cooling methods.

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What Kind of Power Density Dissipation Would it Have Taken to Keep up with Clock Speed Trends?

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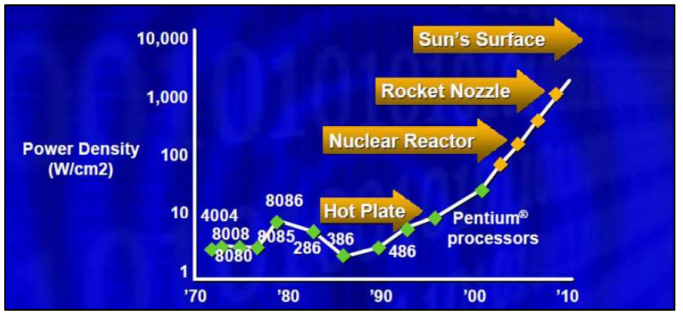

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And speaking of "exotic methods", Intel currently holds the record for Clock Speed: 9.117 GHz

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Tom's Hardware

Cooled with liquid helium (-231 ºC = -394 ºF).
They had to use liquid helium because liquid nitrogen wasn't cold enough. Wow.

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There Are More Sensible Cooling Solutions

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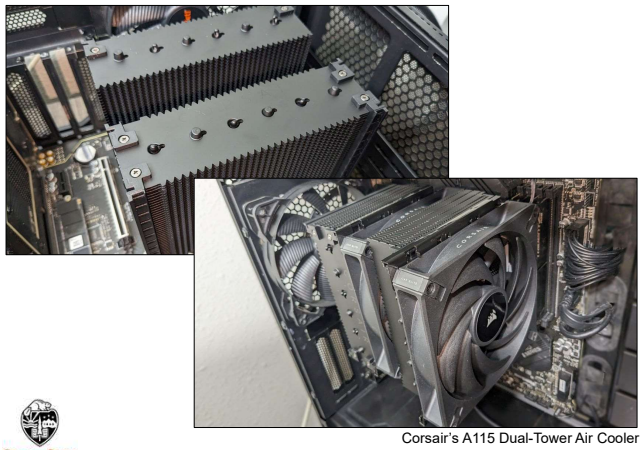

Corsair's A115 Dual-Tower Air Cooler

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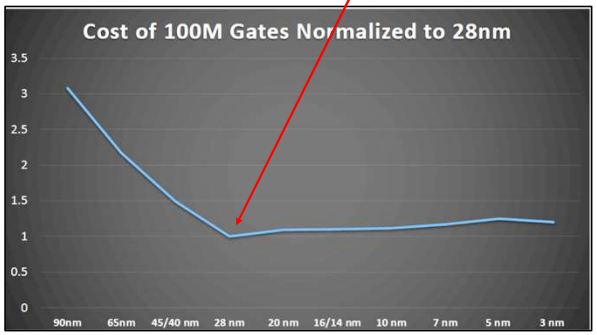
Interestingly, this Size Reduction was Resulting in Cheaper Chips until the Fab Size Hit 28nm



Toms Hardware: February 3, 2024

This has nothing to do with our Moore's Law discussion, I just found it interesting…

MultiCore -- Multiprocessing on a Single Chip

So, to summarize:

Moore's Law of transistor density is still going, but the "Moore's Law" of clock speed has hit a wall. Now what do we do?

We keep packing more and more transistors on a single chip, but don't increase the clock speed. Instead, we increase computational throughput by using those transistors to pack multiple processors onto the same chip.

This is referred to as ***multicore***.

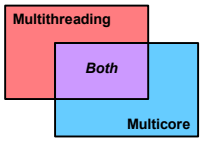
Vendors have also reacted by adding SIMD floating-point units on the chip as well. We will get to that later.

MultiCore and Multithreading

Multicore, even without multithreading too, is still a good thing. It can be used, for example, to allow multiple programs on a desktop system to always be executing concurrently.

Multithreading, even without multicore too, is still a good thing. Threads can make it easier to logically have many things going on in your program at a time, and can absorb the dead-time of other threads.

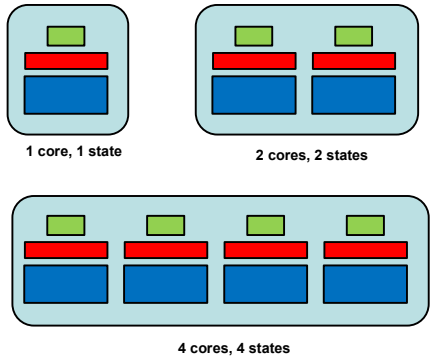
But, the big gain in performance is to use *both* to speed up a *single program*. For this, we need ***a combination of both multicore and multithreading***.

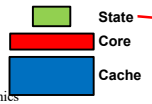


Multicore is a very hot topic these days. It would be hard to buy a CPU that doesn't have more than one core. We, as programmers, get to take advantage of that.

We need to be prepared to convert our programs to run on ***MultiThreaded Shared Memory Multicore*** architectures.

Each of the Multiple Cores keeps its own State





- Registers
- Program Counter
- Stack Pointer

So, if that's what Multicore is about, what is *Hyperthreading*?

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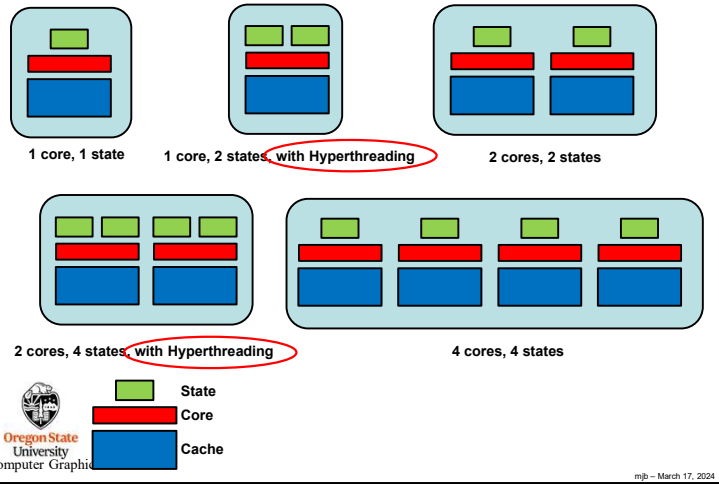

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Four Cores with Two Hyperthreads per Core

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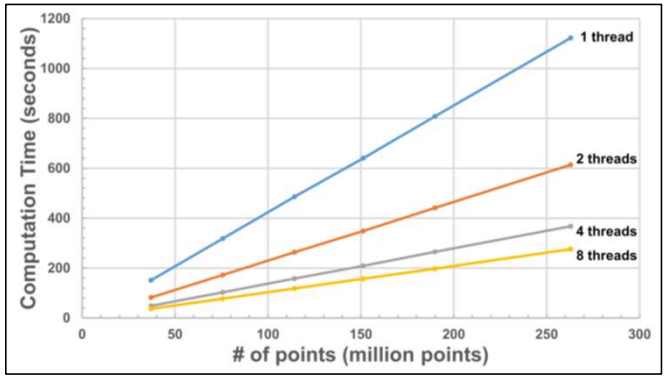

Source: Erzhuo Che

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Note that this is upside-down from our usual convention. Sorry. I got this from someone else.

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