

Parallel Programming: Moore's Law and Multicore



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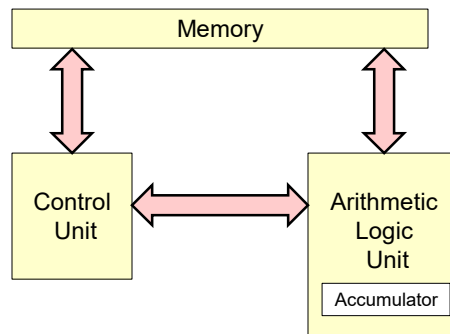


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moores.law.and.multicore.pptx

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



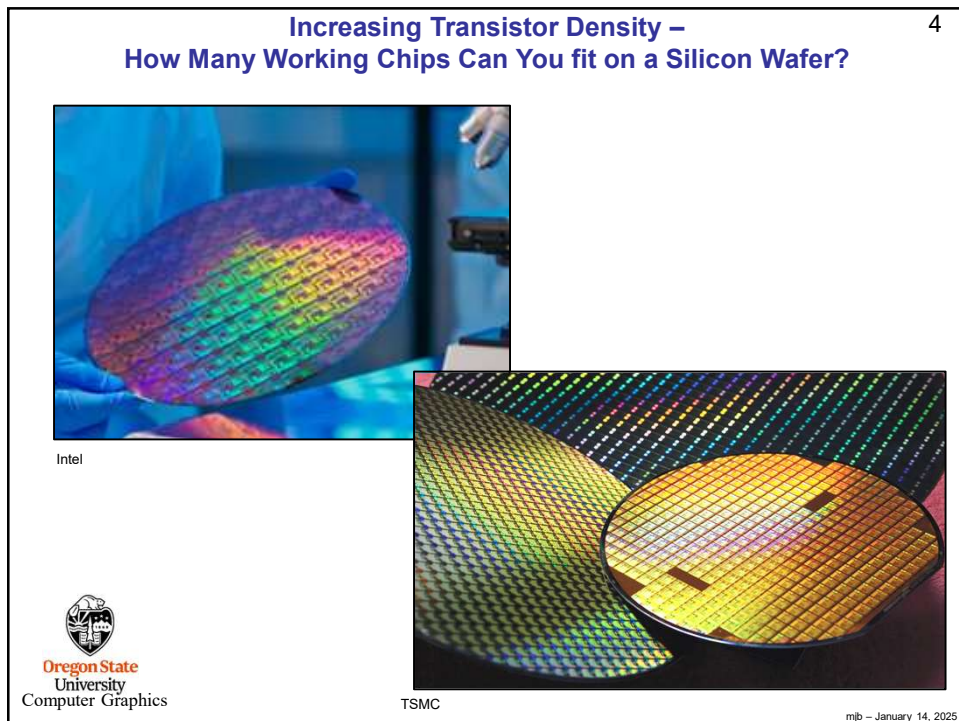
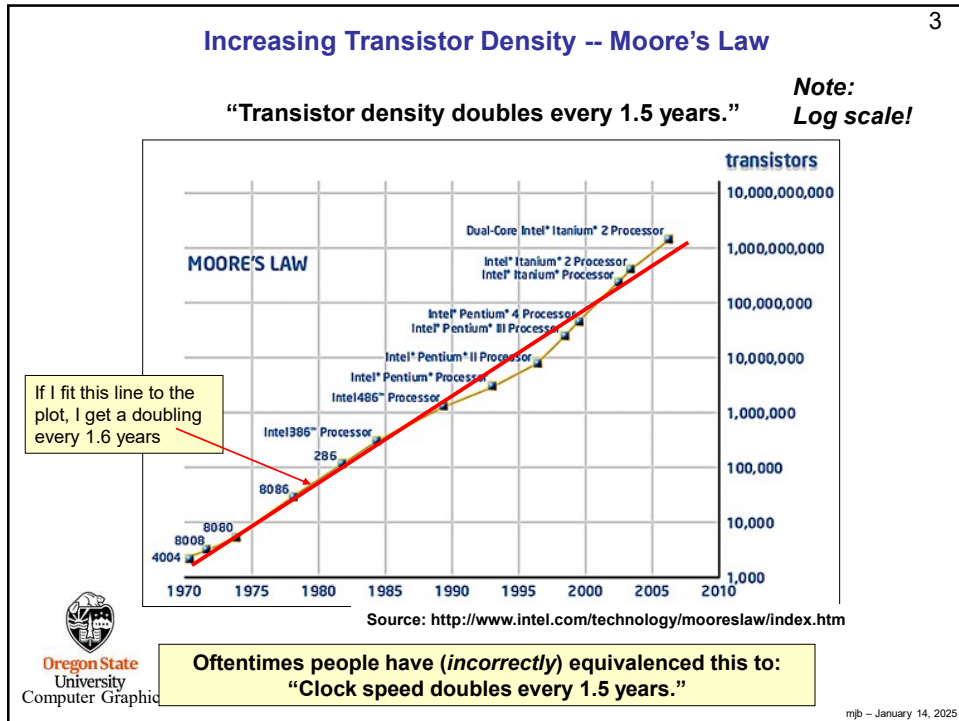
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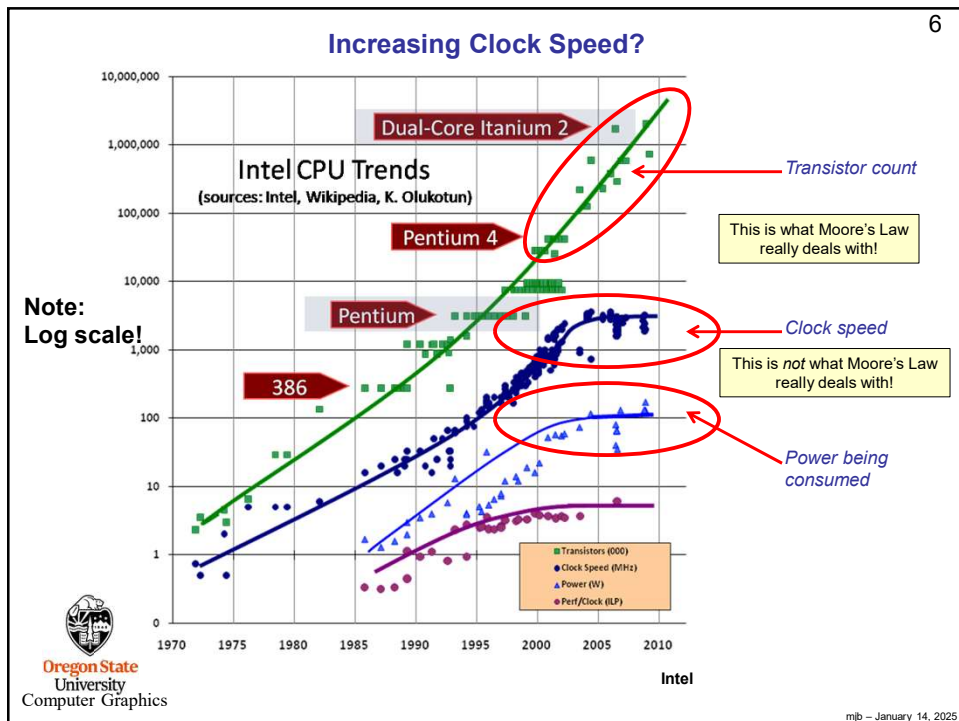
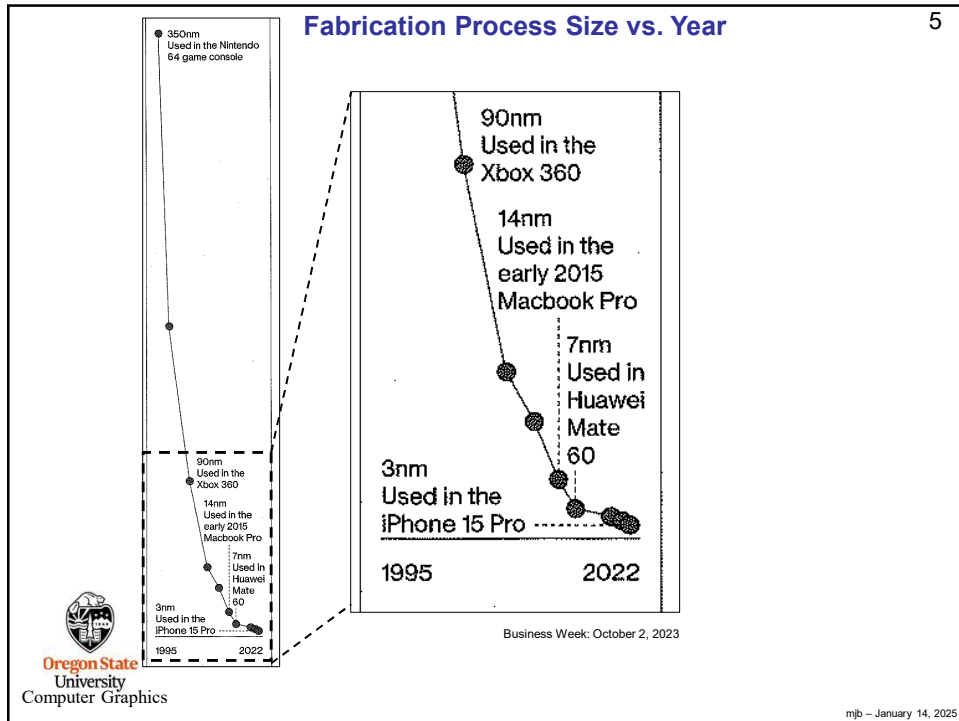
- Clock
- Registers
- Program counter
- Stack pointer



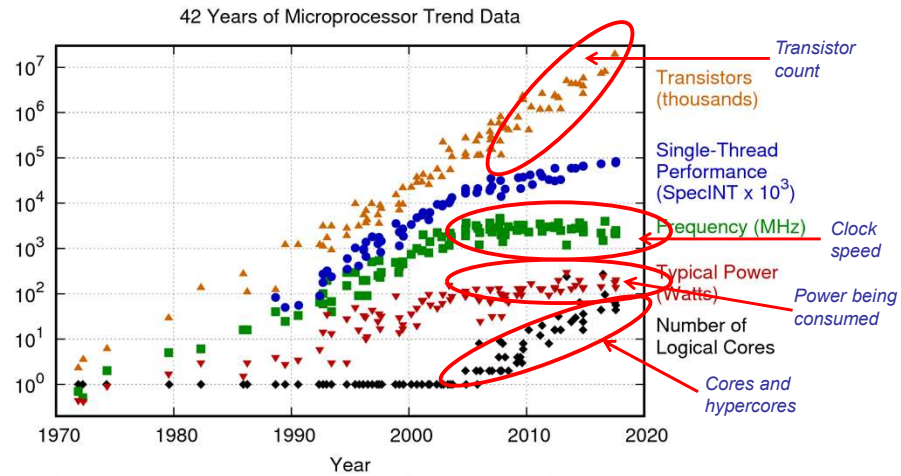
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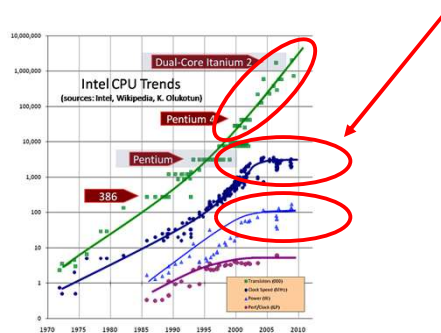


Increasing Clock Speed?



Moore's Law

- 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.



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.

$$\text{PowerConsumption} \propto \text{ClockSpeed}^2$$

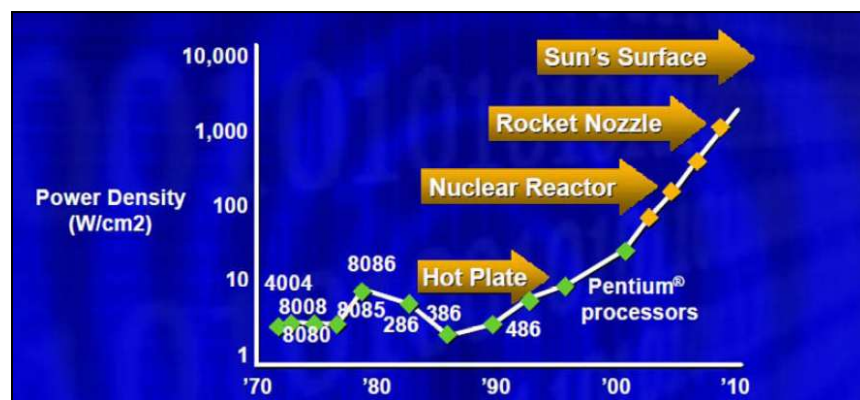
Yikes!

is-proportional-to

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.

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

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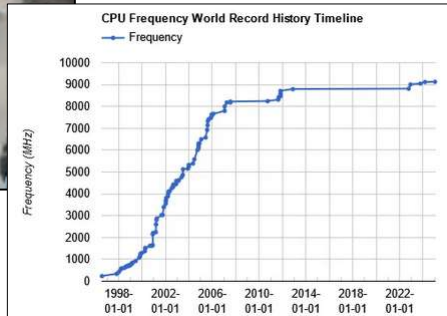
Intel

And speaking of "exotic methods", the current world record for Clock Speed is 9.121 GHz

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Tom's Hardware

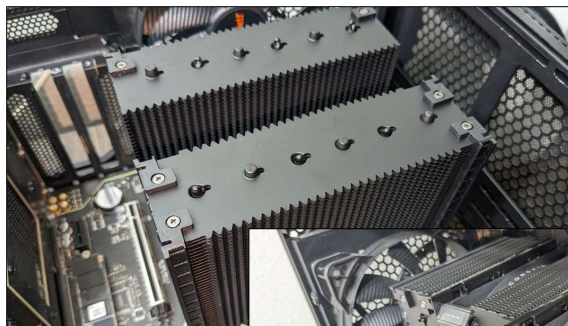


Cooled with liquid helium ($-231^{\circ}\text{C} = -394^{\circ}\text{F}$).
They had to use liquid helium because liquid nitrogen wasn't cold enough. Wow.

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There Are More Sensible Cooling Solutions

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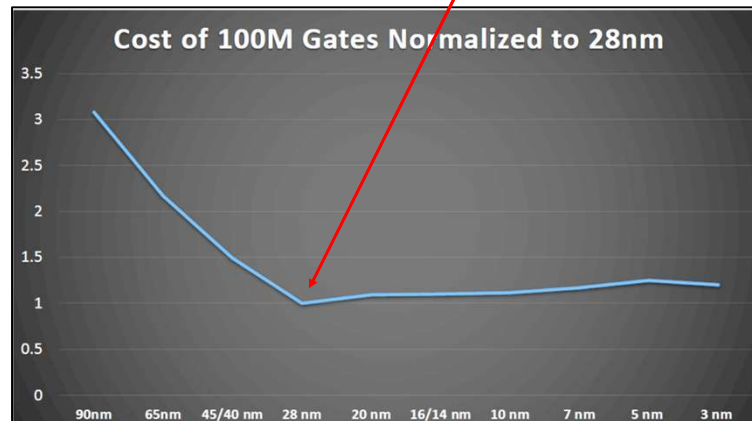
Corsair's A115 Dual-Tower Air Cooler



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

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Toms Hardware: February 3, 2024



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

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MultiCore -- Multiprocessing on a Single Chip

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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.

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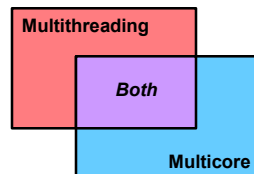
MultiCore and Multithreading

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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.

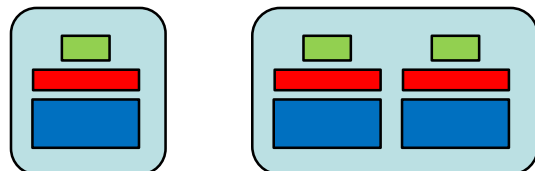


We need to be prepared to convert our programs to run on **MultiThreaded Shared Memory Multicore** architectures.

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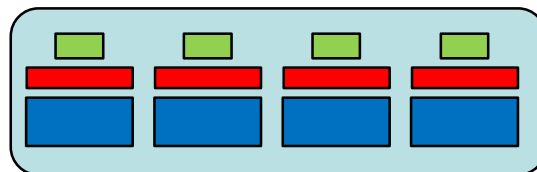
Each of the Multiple Cores keeps its own State

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1 core, 1 state

2 cores, 2 states



4 cores, 4 states

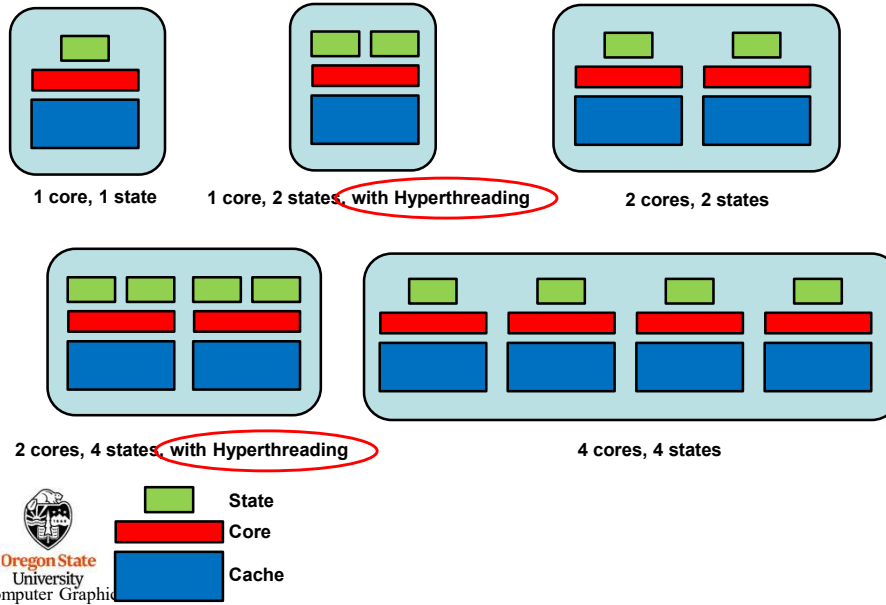


- Registers
- Program Counter
- Stack Pointer

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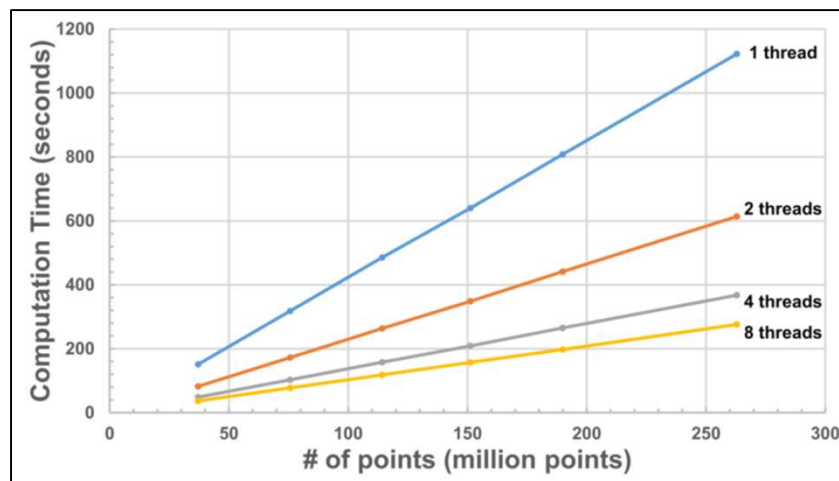
So, if that's what Multicore is about, what is *Hyperthreading*?

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Four Cores with Two Hyperthreads per Core

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Source: Erzhua Che

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