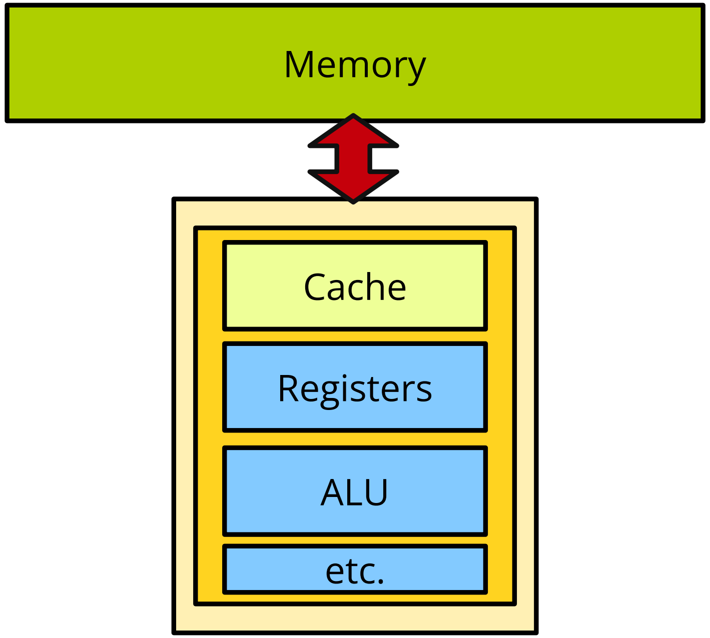
COMP35112 Chip Multiprocessors

Introduction 1

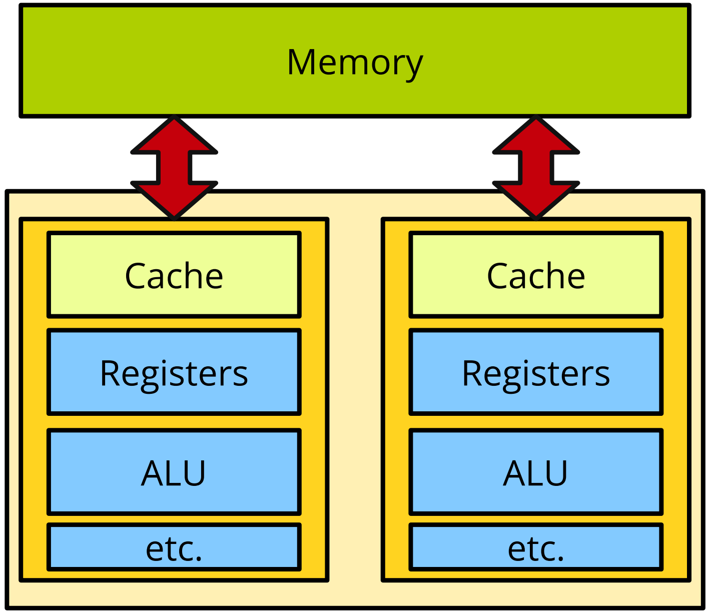
Pierre Olivier

Chip Multiprocessors?



Uniprocessor or single-core CPU

Chip Multiprocessors?



Multiprocessor or multicore CPU

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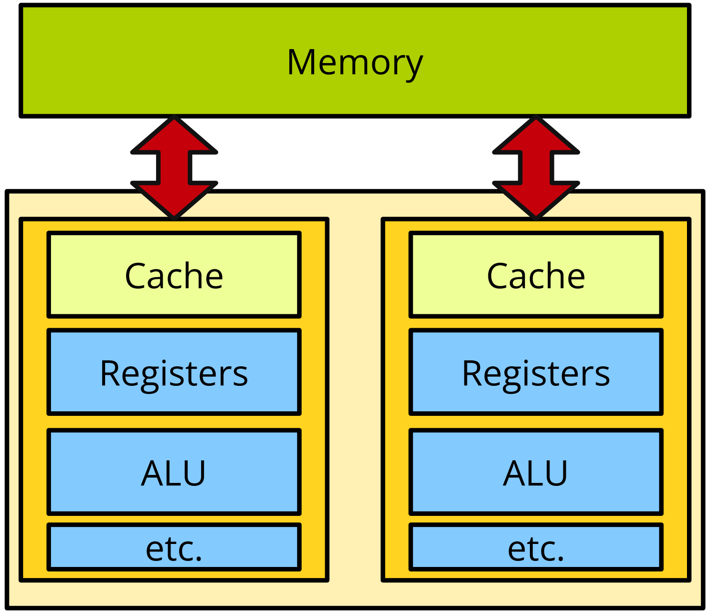
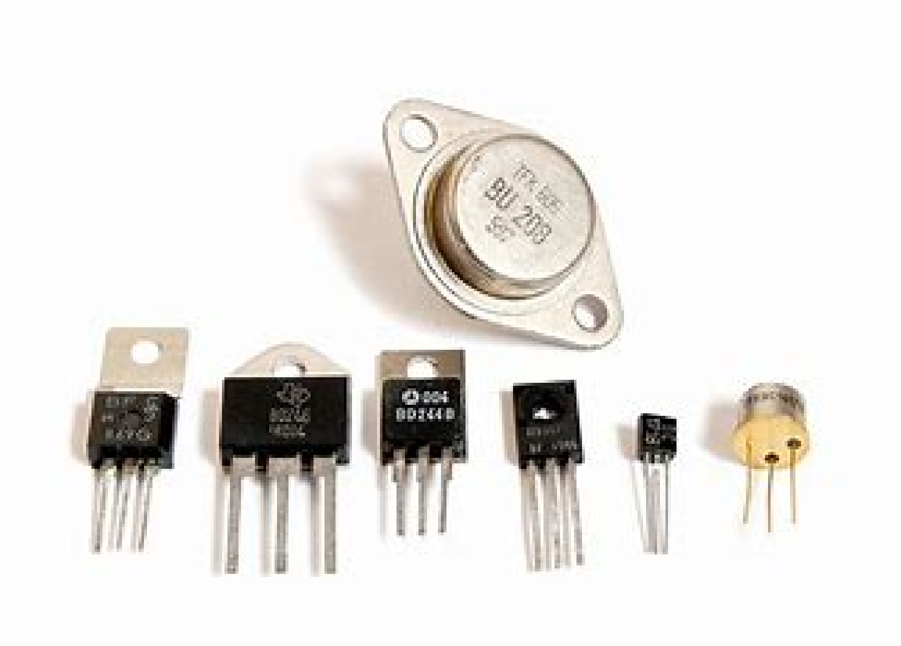


Multiprocessor or multicore CPU

Why was this invented?

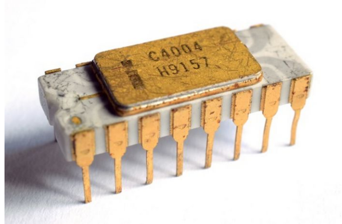
Chip Multiprocessors?



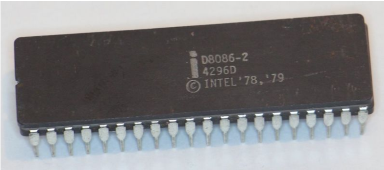
Chip Multiprocessors?

- Computing power of a CPU is function of the number of transistors it integrates

Time 1971 1978 1994 2001

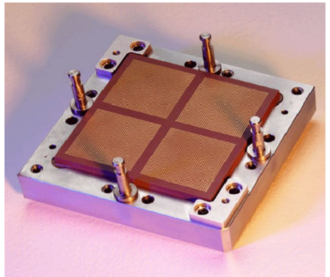


Intel 4004
1st commercial IC processor,
2,300 transistors



Intel 8086,
30K transistors

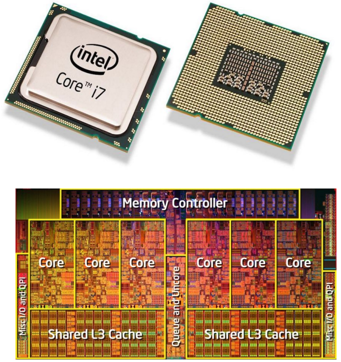
ARM7,
600K transistors



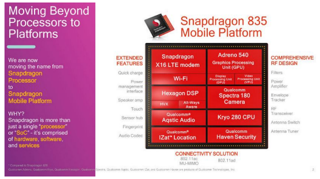
IBM Power4,
170M transistors,
2 cores

Chip Multiprocessors?

Time 2011 2017 2019 2023



6 cores Intel i7, ~1.1 Billion transistors



Moving Beyond Processors to Platforms

We are now moving the name from Snapdragon Processor to Snapdragon Mobile Platform

WHY? Snapdragon is more than just a single "processor" or "SoC" - it's comprised of hardware, software, and services

Snapdragon 835 Mobile Platform

EXTENDED FEATURES
Quick charge
Power management interface
Speaker amp
Touch
Sensor hub
Fingerprint
Audio Codec
Snapdragon X16 LTE modem
Wi-Fi
Hexagon DSP
HVX
All-Ways Aware
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Adreno 540 Graphics Processing Unit (GPU)
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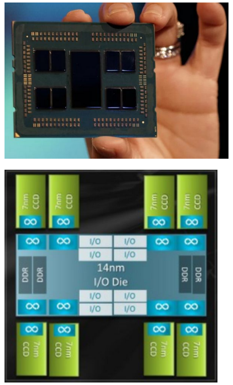
Kryo 280 CPU
Qualcomm Haven Security
COMPREHENSIVE RF DESIGN
Filters
Power Amplifier
Envelope Tracker
RF Transceiver
Antenna Switch
Antenna Tuner
CONNECTIVITY SOLUTION
802.11ac MU-MIMO
802.11ad

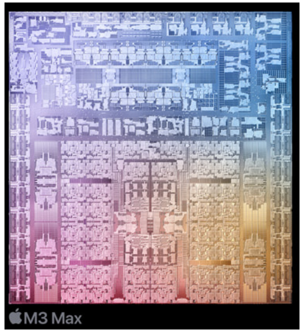
* Compared to Snapdragon 820

Qualcomm Adreno, Qualcomm Kryo, Qualcomm Hexagon, Qualcomm Spectra, Qualcomm Aqstic, Qualcomm IZat, and Qualcomm Haven are products of Qualcomm Technologies, Inc.

Qualcomm Snapdragon 835 SoC (Quad core, GPU, DSP...), ~3 Billion transistors



64 cores AMD EPYC Rome, 40 Billion transistors



14 cores CPU + 18 cores GPU Apple M3 Max, 92 Billion transistors

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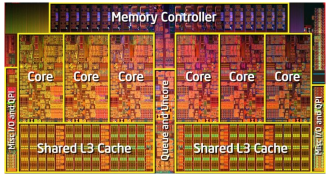

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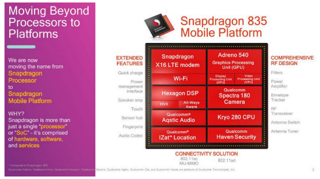

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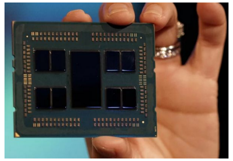

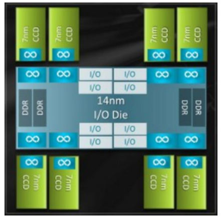

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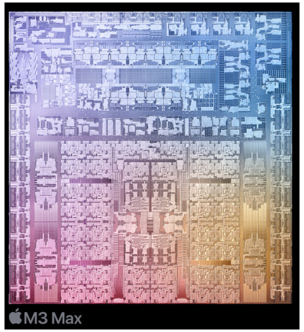

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Why this increase in number of compute units (cores) per chip?

Core Count Increase

- For decades we have seen a continual increase in single-core processors **speed**
- Transistors get (significantly) smaller, circuits get (a bit) bigger, **clock frequency increase**
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- Power consumption and heat dissipation → **clock speed stalled**
- **Architectural approaches to increase single processor speed have been exhausted**

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- Processors don't get faster, but we can still put more transistors in a single integrated circuit
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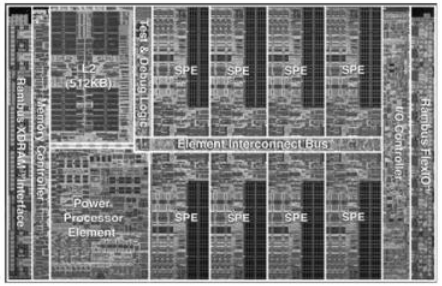
    - **Software issues**: how do we program this thing?



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    - Feature size (basically transistor size)
        - Intel 386 (1985): 1.5 um
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- Increase in transistors/chip mostly due to **transistor size reduction**

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- Due to electric properties:
    - Smaller transistors have a faster switch delay
    - **They can be clocked at a higher frequency**
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- **But we hit limits**
  - Power density increases, heating becomes a problem

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    - Transistors get smaller, so they consume less power as we pack more on the same chip
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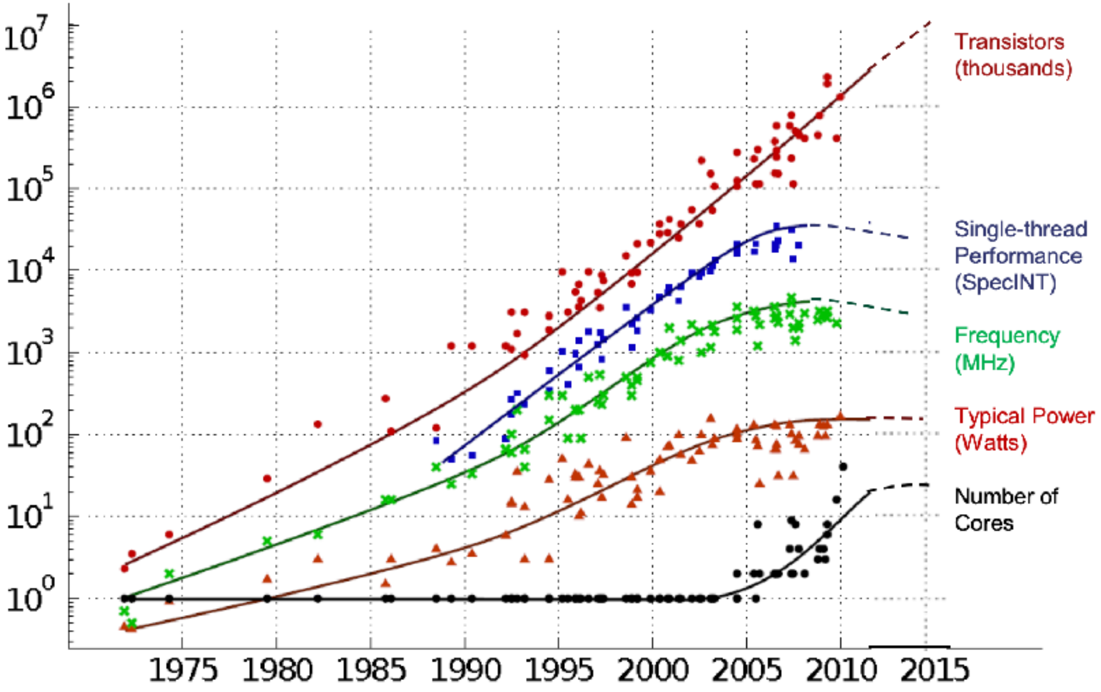
  - Transistors get smaller, so they consume less power as we pack more on the same chip
  - Power density stay constant → no power consumption/heating problem 👍
  - **Broke down in the mid-2000s** 🥲
    - Mostly due to the high current leakage with small transistor sizes

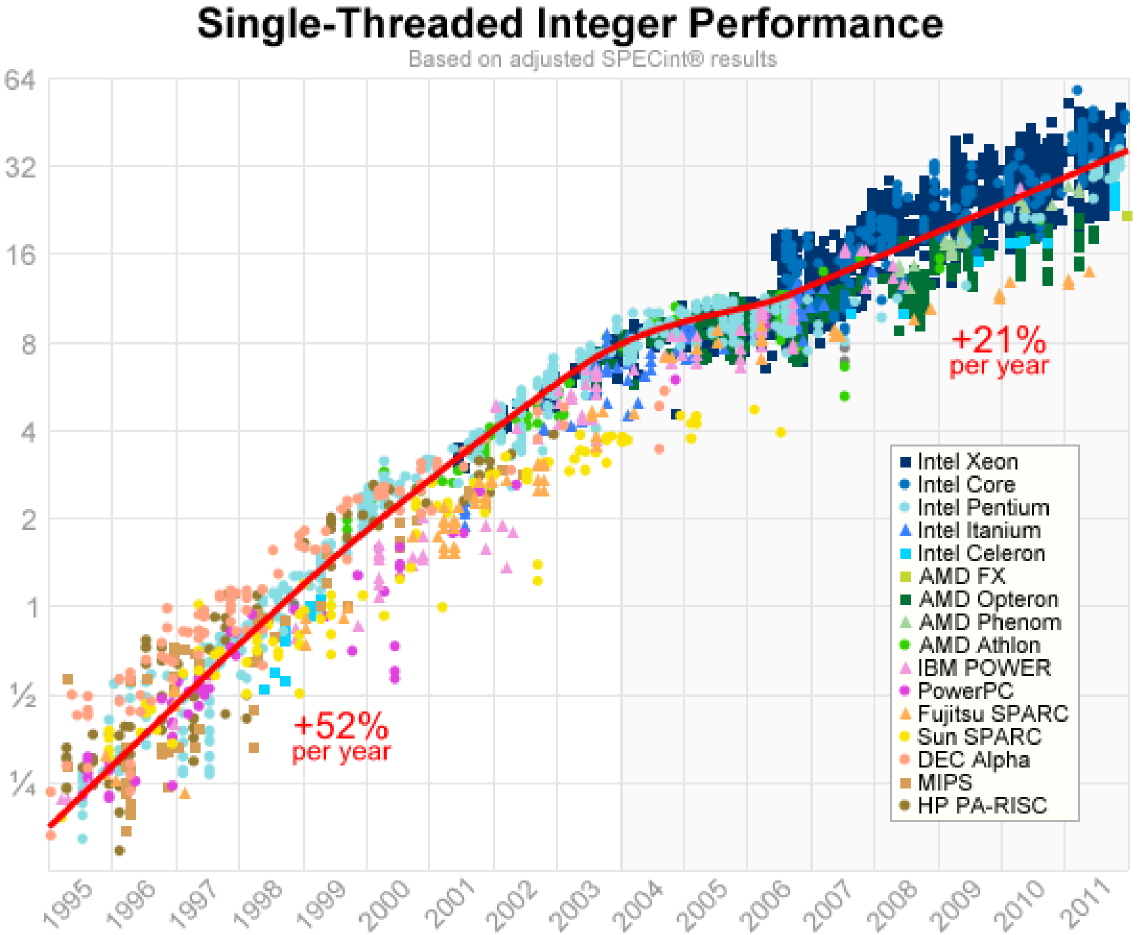
End of Dennard Scaling



Original data collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond and C. Batten
Dotted line extrapolations by C. Moore

End of Dennard Scaling: Frequency can't keep increasing because power can't be removed from the chips, they'd melt!

Single Core Performance



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- How to use these extra transistors to get faster?
  - Can we build ***faster single-core processors?***
    - **More parallel pipelines** to exploit Instruction Level Parallelism?
      - ILP has diminished returns beyond ~4 pipelines
    - **Bigger caches**:
      - Payback for bigger caches also diminishes rapidly

The "Solution": Multiple Cores

- Put multiple CPUs (cores) on a single integrated circuit (chip)
    - **"Multicore chip" or "Chip Multiprocessor"**
- Use these CPUs in parallel to achieve higher performance
- Simpler to design vs. increasingly complex single core CPUs
- Need more computing power? Add more cores ...
    - ... not that simple in practice, 2 * 3GHz != 6GHz

Multicore "Roadmap"

- Year, cores per chip, feature size

- 2006, ~2 cores, 65nm
- 2008, ~4 cores, 45nm
- 2010, ~8 cores, 33nm
- 2012, ~16 cores, 23nm
- 2014, ~32 cores, 16nm
- 2016, ~64 cores, 12nm
- 2018, ~128 cores, 8nm
- 2020, ~256 cores, 6nm
- 2022, ~512 cores, 4nm
- 2024, ~1024 cores, 3nm
- 2026, ~2048 cores, 2nm
- *scale discontinuity?*
- 2028, ~4096 cores
- 2030, ~8192 cores
- 2032, ~16384 cores

Summary

- Single core performance hit a plateau in the mid 2000s
- To address that issue constructors started to pack more cores on a single chip
- Next: **how to efficiently exploit the resulting parallelism**?