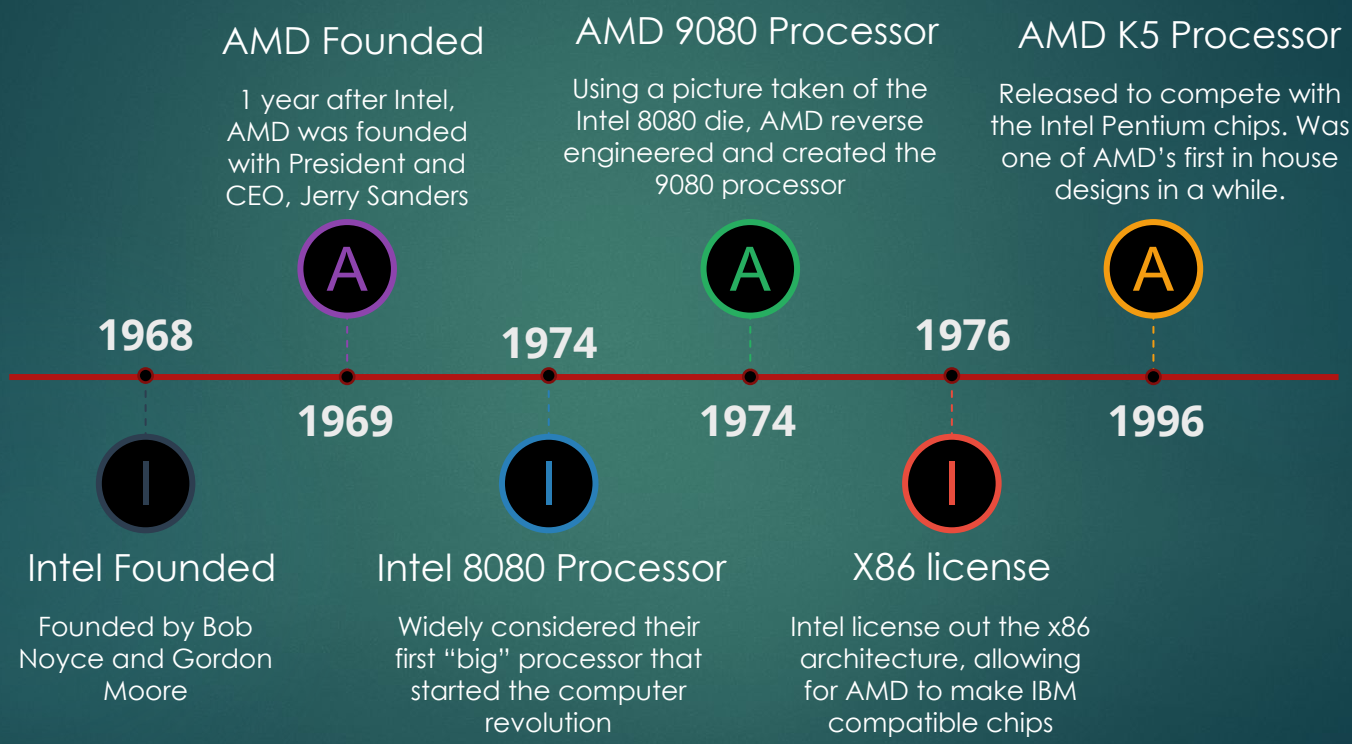
Intel and the Core i7

Andrew Levy, Timothy Winters, Daniel Duff, Matthew Hagan, Jake Freise, Henry Frishman, Norman Delorey

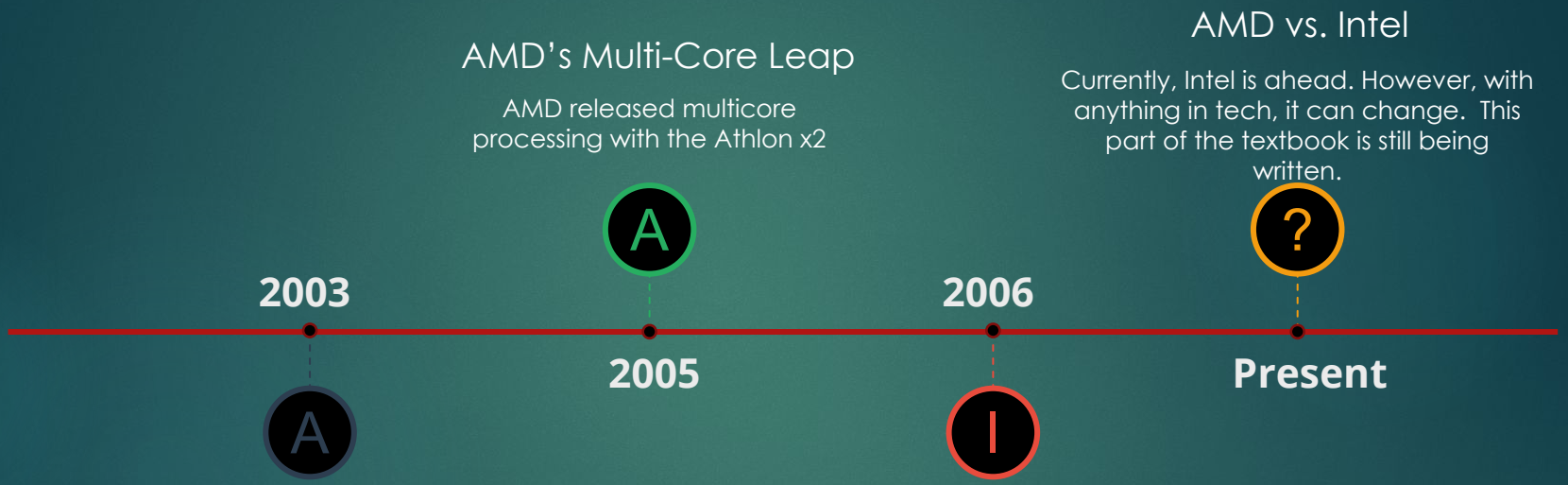
Intel vs. AMD

The Early History of Tech's Oldest Rivalry

Tech's Oldest Rivalry: Early History



Tech's Oldest Rivalry: Early 2000's



Tech's Oldest Rivalry: Intel (The Top Dog)

- Intel is a much larger company than AMD
- They do more general applications that other component manufacturers build around
- Their products are primarily "in house", meaning that they fabricate their own chips.
  - This fabrication is a global process, with over 12 plants worldwide
- Intel's CPU's typically draw less power and have a lower Thermal Design point (TDP) rating through the use of Hyperthreading

Tech's Oldest Rivalry: AMD (The underdog)

- AMD is the smaller company
- They do a lot of 1-off chips for custom applications
- AMD does not make their own chips anymore, but rather outsources the manufacturing.
- AMD does not do hyperthreading
  - Instead, they utilize overclocking, which is when the CPU/GPU runs at a higher clock rate than originally designed. AMD has a history of Overclocking better than Intel

Tech's Oldest Rivalry: Textbook view

Single Processor Performance

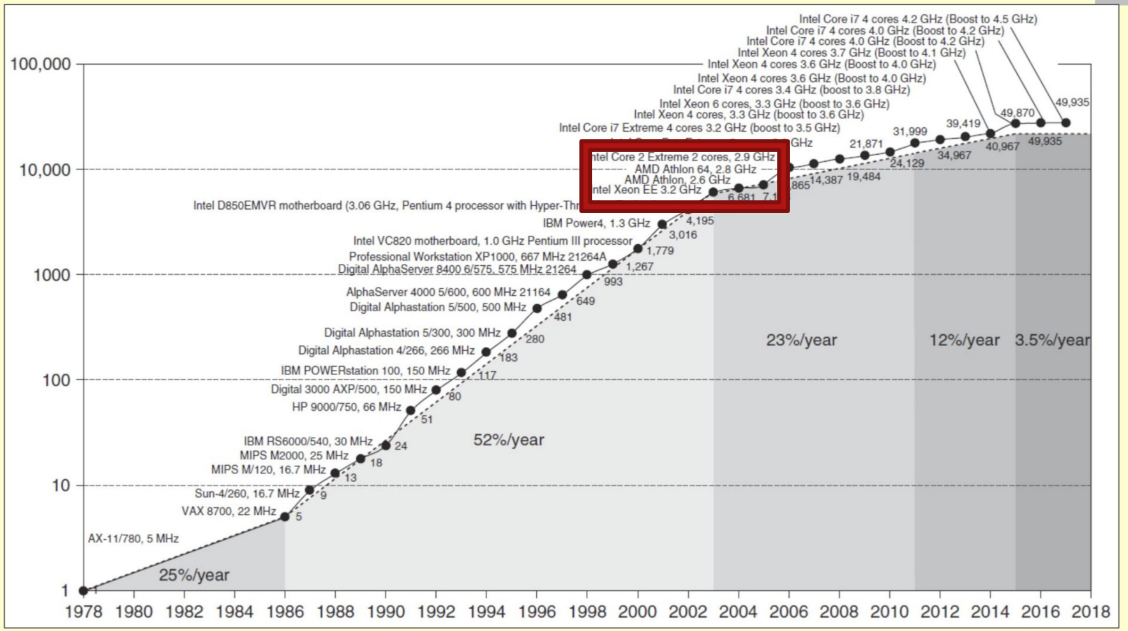


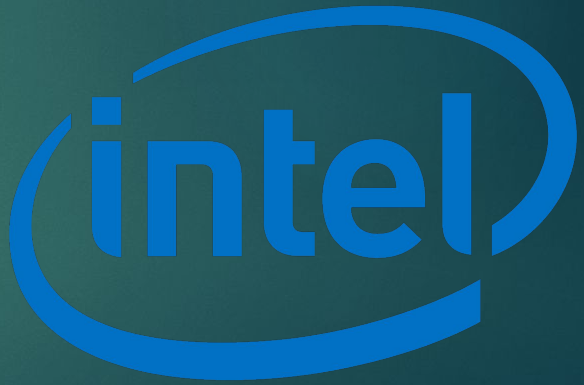
Figure 1.1

Intel Core i7

A breakdown of generations

Intel Core i7 Overview

- Family of 64 bit processors designed by intel
- Succeeds Penryn microarchitecture
- Released alongside i3 and i5
- Grouped into generations (starting in 2009)



Generation 1 - Nehalem

- Named after Nehalem River
- Improved clock speeds
- Reduction of size of L2 cache
- Increase in size of L3 cache (shared among all cores)
- Reintroduced hyperthreading

Generation 2 - Sandy Bridge

- Named after Silicon and original name Gesher

  (which means bridge in Hebrew)
- Intel Turbo Boost 2.0
- Integrated Graphics
- Redesigned cores

Generation 3 and 4 - Ivy Bridge and Haswell

- Ivy Bridge (2011)
  - First microarchitecture to support Windows 10
  - Transistor size shrink from 32 nm to 22 nm
  - Significantly hotter when overclocked
- Haswell (2013)
  - Named after Haswell, Colorado
  - Wider cores

Generation 5 - Broadwell

- Named after Broadwell, Illinois
- Very similar to Haswell
- Second Level TLB enlarged
- Fully integrated Voltage Regulator (FIVR)
- Larger scheduler (64 entries) and instruction queue (25 entries)

Generation 6 and 7 - Skylake and Kaby Lake

- Skylake (2015)
  - Biggest performance increase
  - Improved branch prediction unit
  - Removal of FIVR
- Kaby Lake (2016)
  - Very similar to Skylake
  - Largest improvements for mobile processors

Generation 8 - Coffee Lake

- Coffee Lake (2017)
  - Features Six Cores
  - Increased L3 cache
- Coffee Lake Refresh (2018)
  - Introduction of the i9
  - Features Eight Cores
  - Removed hyperthreading from newer i7's

Why i7?

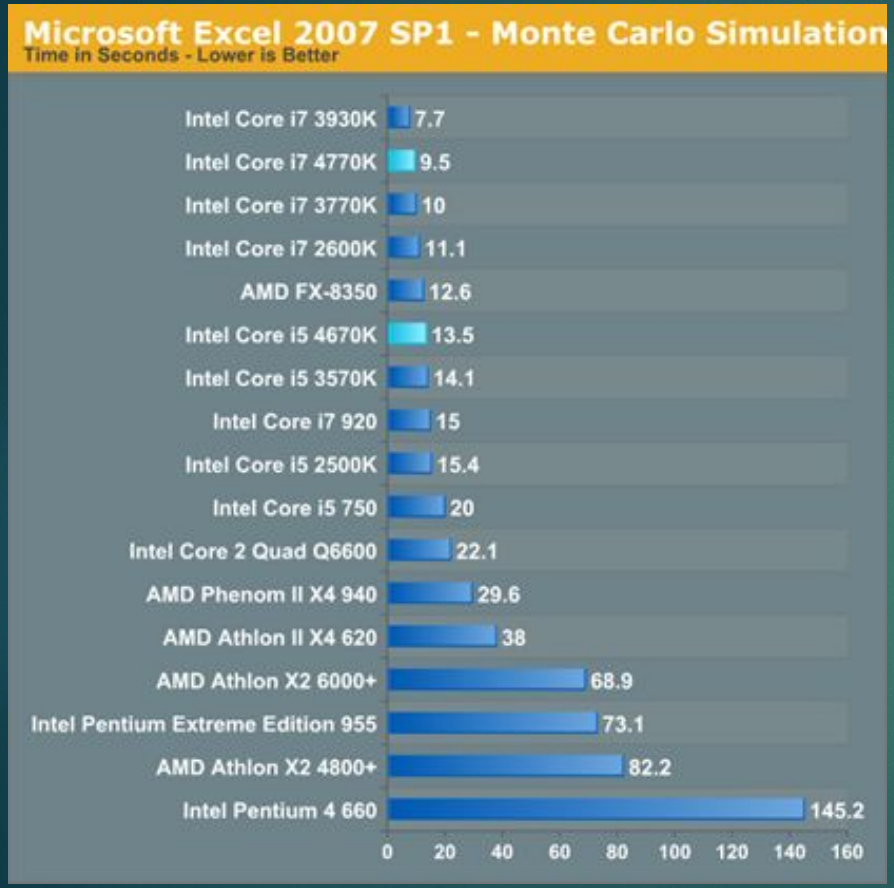
What makes these chips so great

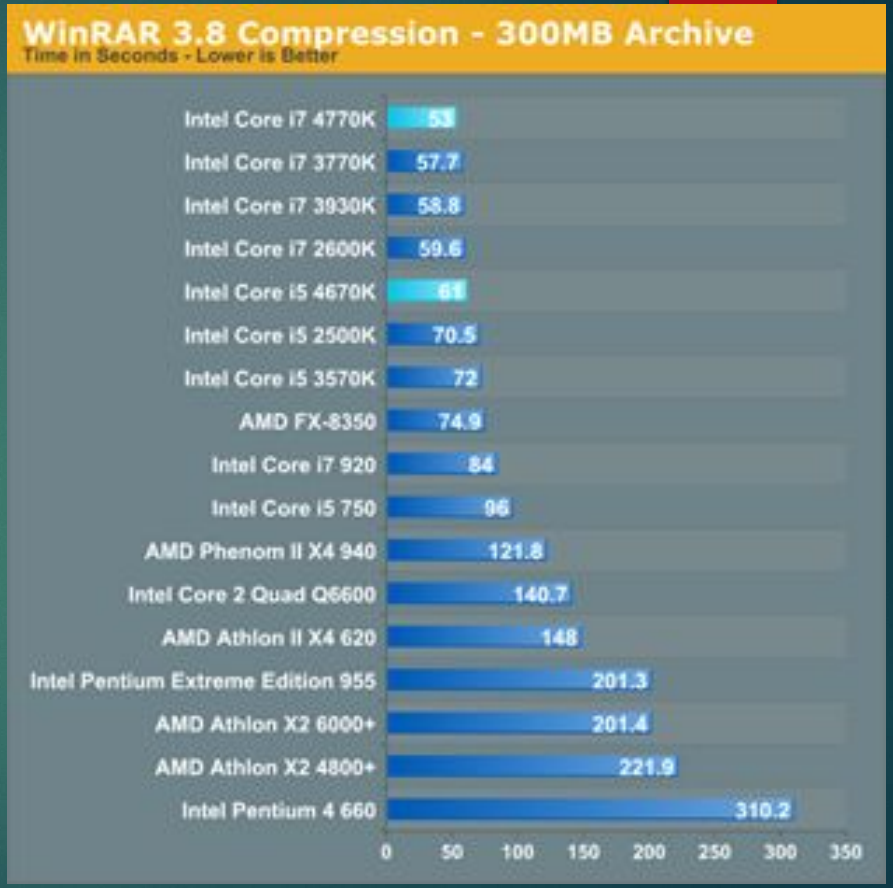
What's so great about intel chips?

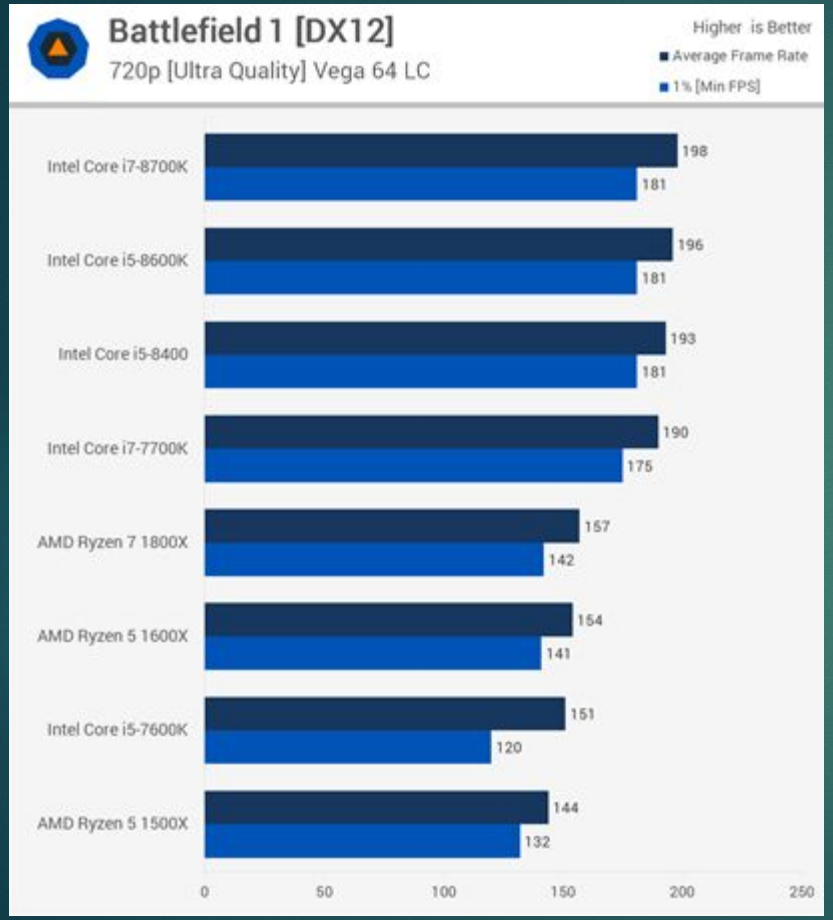
- Good speed/price value
  - ~$140 - 350 (i3 - i7)
- Advertise well
  - Laptop and desktop manufacturer agreements
  - Appends advertisements onto manufacturers'
- Wide variety of applications
  - Desktops, laptops, mobile (26 mm)

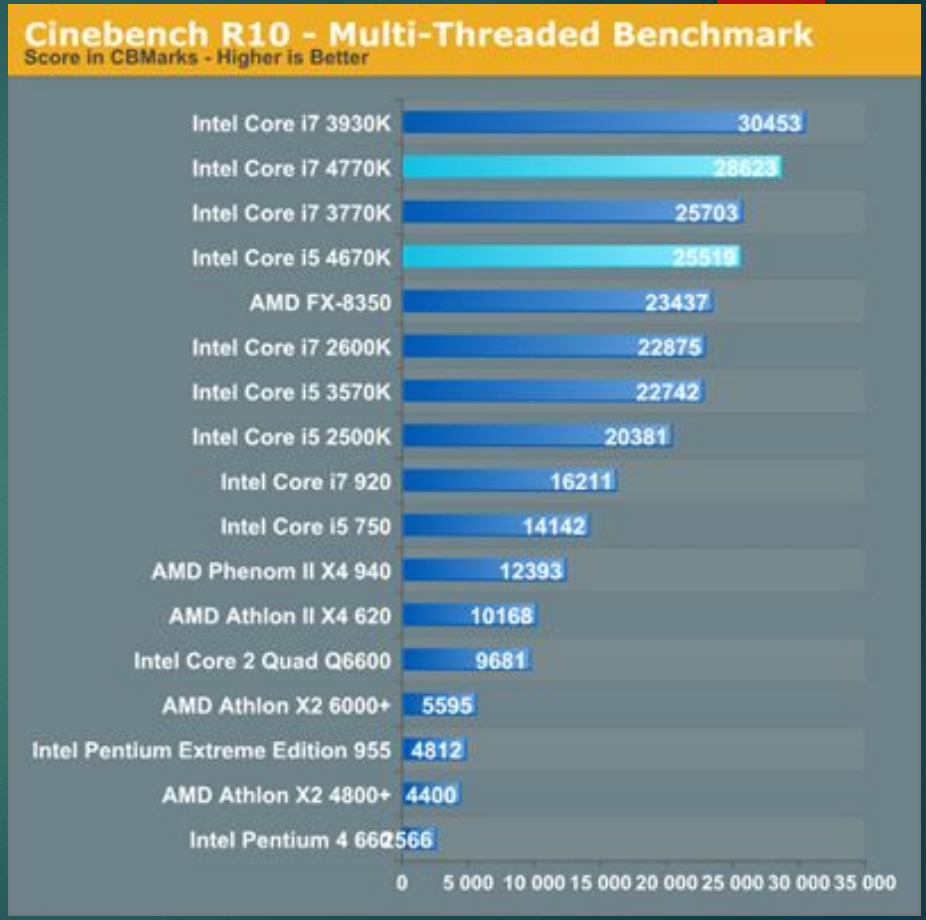
What's so great about the i7?

- Lower overall heat and power
  - ~38 Celsius/100 Fahrenheit
  - 35-140 Watts
- x86 Instruction set & Integrated Memory
- Multi-GPU compatible, integrated graphics
- Hyperthreading (4 Core), turbo boost, k model
- Xeon chips for servers and high-end workstations
  - Error Checking and System Management features
  - Up to 8,000,000,000 transistors vs 730,000,000


Microsoft Excel 2007 SP1 - Monte Carlo Simulation
Time in Seconds - Lower is Better
Intel Core i7 3930K 7.7
Intel Core i7 4770K 9.5
Intel Core i7 3770K 10
Intel Core i7 2600K 11.1
AMD FX-8350 12.6
Intel Core i5 4670K 13.5
Intel Core i5 3570K 14.1
Intel Core i7 920 15
Intel Core i5 2500K 15.4
Intel Core i5 750 20
Intel Core 2 Quad Q6600 22.1
AMD Phenom II X4 940 29.6
AMD Athlon II X4 620 38
AMD Athlon X2 6000+ 68.9
Intel Pentium Extreme Edition 955 73.1
AMD Athlon X2 4800+ 82.2
Intel Pentium 4 660 145.2
0 20 40 60 80 100 120 140 160


WinRAR 3.8 Compression - 300MB Archive
Time in Seconds - Lower is Better
Intel Core i7 4770K 53
Intel Core i7 3770K 57.7
Intel Core i7 3930K 58.8
Intel Core i7 2600K 59.6
Intel Core i5 4670K 61
Intel Core i5 2500K 70.5
Intel Core i5 3570K 72
AMD FX-8350 74.9
Intel Core i7 920 84
Intel Core i5 750 96
AMD Phenom II X4 940 121.8
Intel Core 2 Quad Q6600 140.7
AMD Athlon II X4 620 148
Intel Pentium Extreme Edition 955 201.3
AMD Athlon X2 6000+ 201.4
AMD Athlon X2 4800+ 221.9
Intel Pentium 4 660 310.2
0 50 100 150 200 250 300 350


Battlefield 1 [DX12]
720p [Ultra Quality] Vega 64 LC
Higher is Better
Average Frame Rate
1% [Min FPS]
Intel Core i7-8700K
198
181
Intel Core i5-8600K
196
181
Intel Core i5-8400
193
181
Intel Core i7-7700K
190
175
AMD Ryzen 7 1800X
157
142
AMD Ryzen 5 1600X
154
141
Intel Core i5-7600K
151
120
AMD Ryzen 5 1500X
144
132
0
50
100
150
200
250


Cinebench R10 - Multi-Threaded Benchmark
Score in CBMarks - Higher is Better
Intel Core i7 3930K
30453
Intel Core i7 4770K
28623
Intel Core i7 3770K
25703
Intel Core i5 4670K
25516
AMD FX-8350
23437
Intel Core i7 2600K
22875
Intel Core i5 3570K
22742
Intel Core i5 2500K
20381
Intel Core i7 920
16211
Intel Core i5 750
14142
AMD Phenom II X4 940
12393
AMD Athlon II X4 620
10168
Intel Core 2 Quad Q6600
9681
AMD Athlon X2 6000+
5595
Intel Pentium Extreme Edition 955
4812
AMD Athlon X2 4800+
4400
Intel Pentium 4 662
2566
0
5 000
10 000
15 000
20 000
25 000
30 000
35 000

Key Differences

- Hyper-threading: Core virtualization
- Turbo-Boost: Automatic Overclocking
- K model: Easier Overclocking

Model	Core i3	Core i5	Core i7
Number of cores	2	4	4+
Hyper-threading	Yes	No	Mostly
Turbo boost	No	Yes	Yes
K model	No	Yes	Yes

I7 vs. Xeon

What's the difference?

I7 vs Xeon

- **Myth:** Xeons and i7s do not work with the same motherboard
  - This used to be true, now it depends on the motherboard

- **Myth:** Xeons are inherently better for multicore workloads and i7s are better for single core
  - If they are based on same micro-architecture and have the same specifications they should perform the same.

I7 vs Xeon

Why use a Xeon?

- Error-Correcting Code (ECC) memory support
  - When you cannot afford a crash
- Intended to run 24/7
  - Important for servers
- Large memory per CPU and has a large L3 cache
  - Increases performance on repetitive processes
- Offer specialized options that isn't needed at the consumer level
  - Virtualization features, compatible with multi-socket motherboards
- More possible cores
  - Up to 48

I7 vs Xeon

Why not use a Xeon?

- Cost
  - Xeons are marketed to data centers which value performance per watt and i7's tent to have higher Ghz per dollar
- No Overclocking
  - Xeons cannot be overclocked, i7's can
- No integrated graphics
  - Xeons do not come with integrated graphics, where as i7s do
- No quick sync video
  - Dedicated core for transcoding ("converting") video allowing

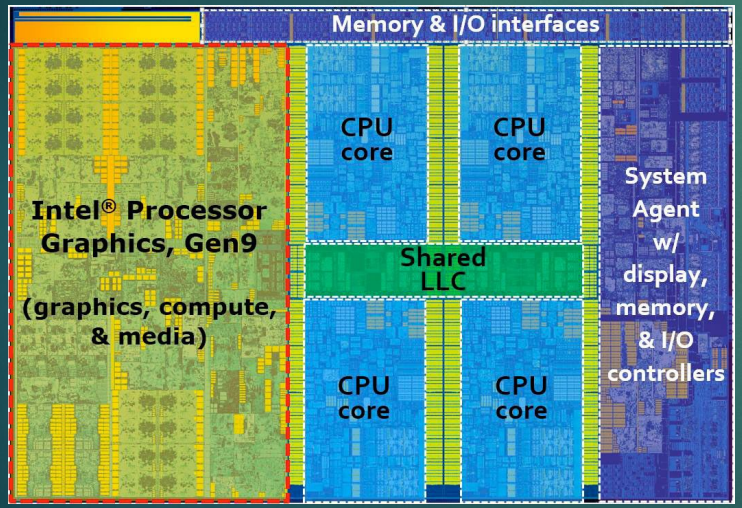
i7 Breakdown

Architecture, memory hierarchy, and more

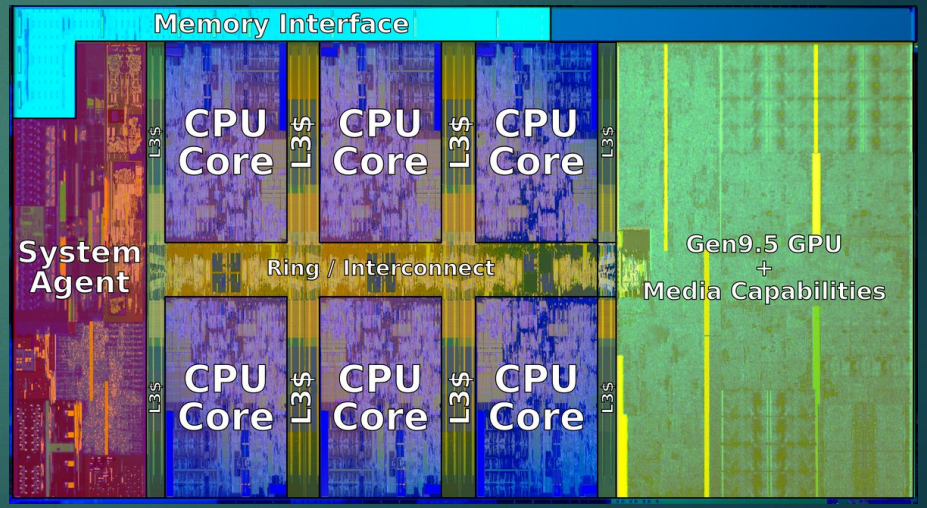
Intel's Manufacturing Process

Physical architecture

Skylake (4 Core)



Coffee Lake (6 Core)



Memory Hierarchy

- Contains an L1 & L2 cache per core
- L3 cache is shared among all cores
- The L1 caches are split into halves for instructions and data
- All write-back

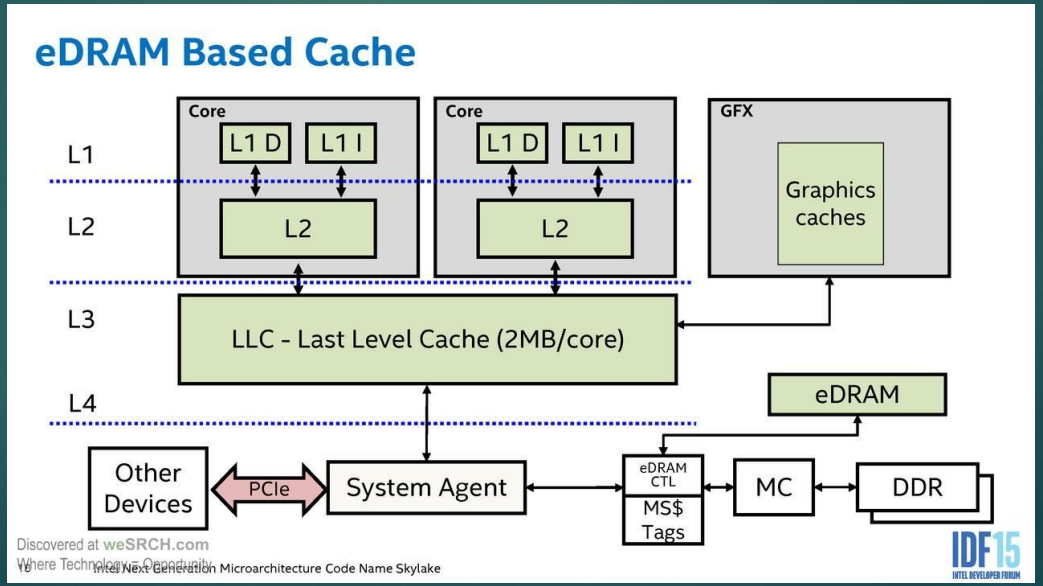
L1 Cache

- Split into 2 parts, for memory and instructions

  (Harvard Architecture)
- 32KB
- 64 bytes per line
- Has a minimum latency of 4 cycles
- Built directly into the core

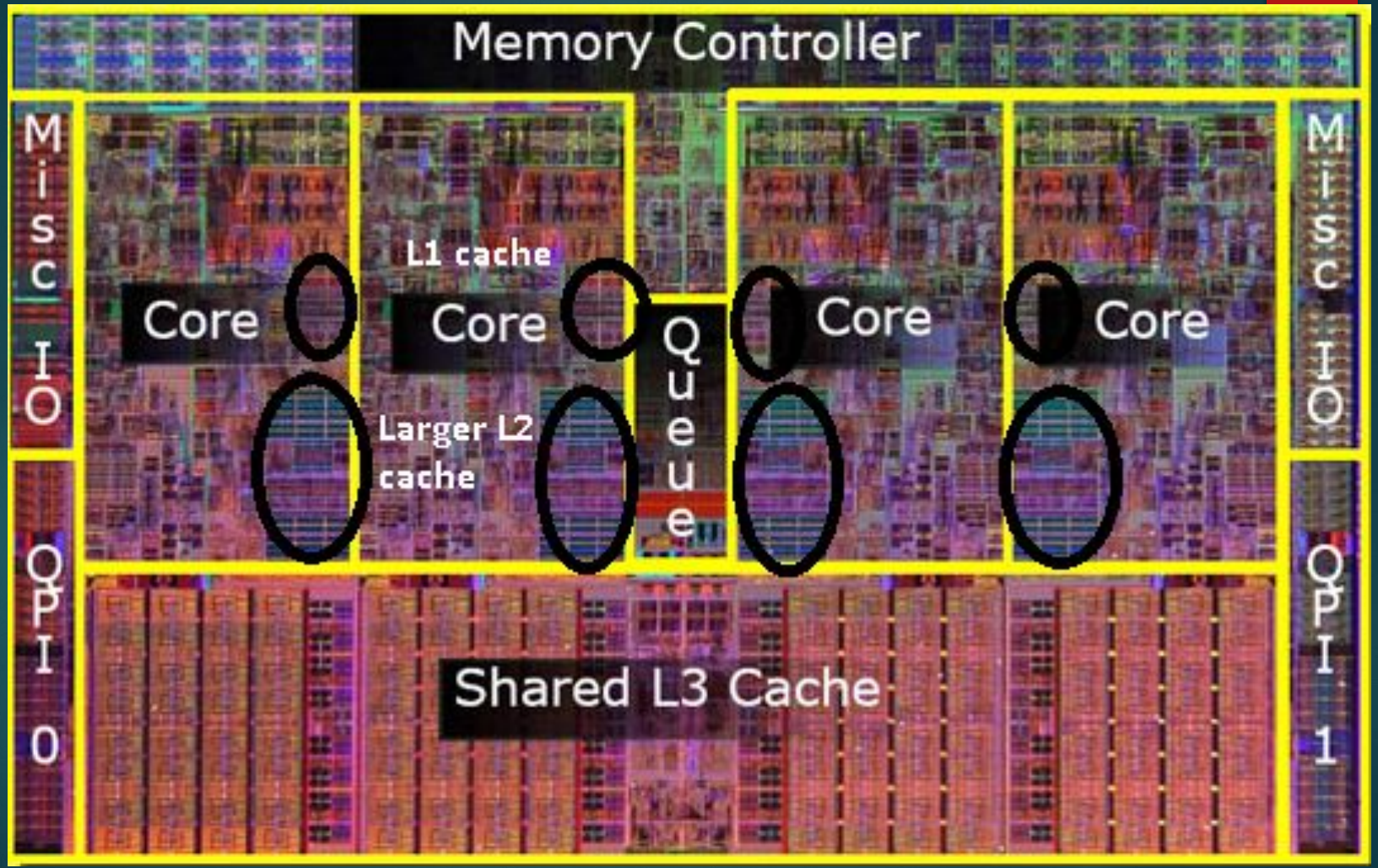
L2 Cache

- 256KB
- 64 bytes per line, same as L1
- Minimum latency of 12 cycles

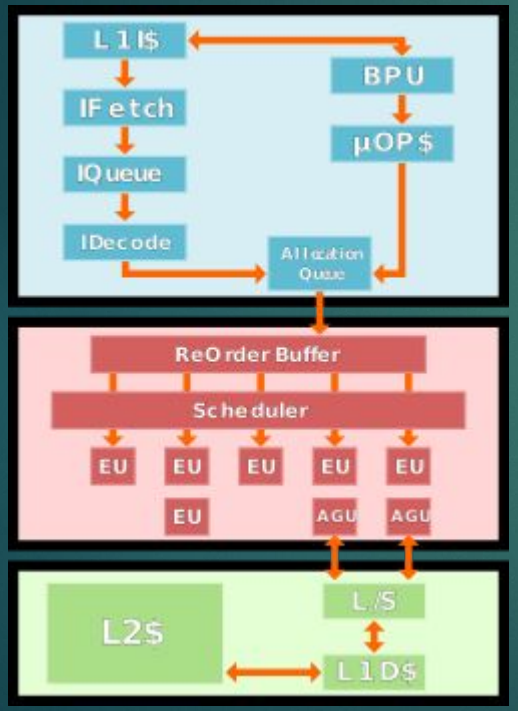


L3 Cache

- Unique as it is shared among all 4 cores
- Size varies between 6-15 MB from generation to generation
- 36 cycles minimum
  - Cycle count is predicted to vary dramatically with next gens
- The size is sometimes reduced for power efficiency within mobile

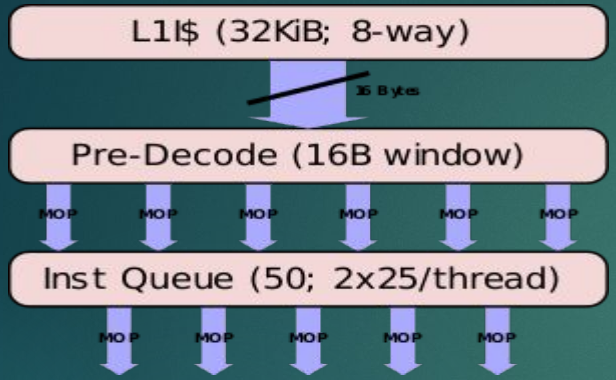

Memory Controller
Misc IO
Misc IO
L1 cache
Core
Core
Core
Core
Queue
Larger L2 cache
QPI 0
QPI 1
Shared L3 Cache

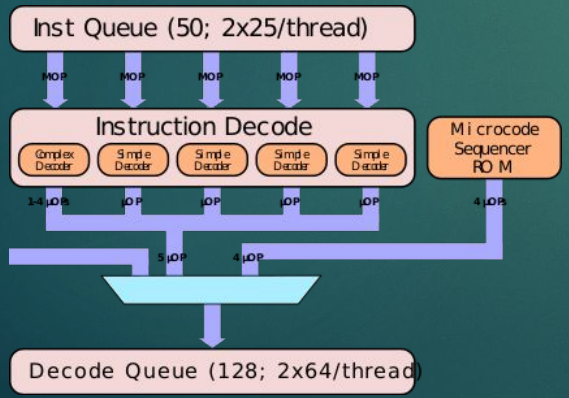
Pipelining in the i7



- The i7 Pipeline has 3 main areas:
- The "Front End"
  - Instruction fetching
  - Instruction decoding
- The "Back End"
  - Instruction scheduling
  - Instruction execution
- Memory Operations

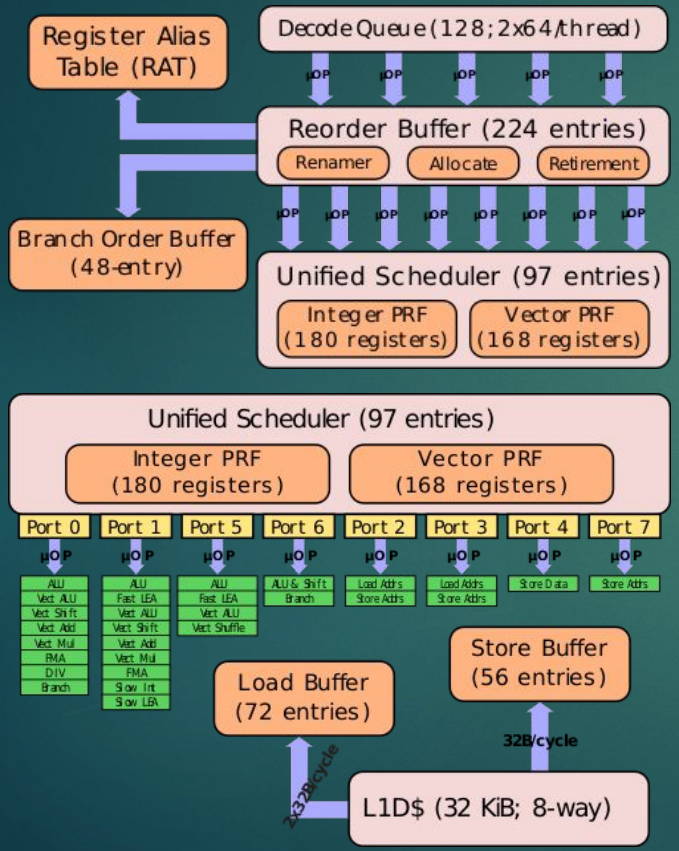
The Front End





- Instructions must be pre-decoded
  - Marks the boundaries within the instruction
  - Throughput of 6 instructions per cycle or 16 bytes
- Instructions are then decoded into micro-ops
  - Complex decoders can output 1 to 4 fused micro-ops
  - Simple Decoders output 1 micro-op
  - The Microcode Sequencer is used for instructions larger than 4 micro-ops
- Micro-ops are also cached by the branch predictor
  - Have a throughput of up to 6 micro-ops

The Back End



- Reorder Buffer
  - Where reordering, renaming, and retiring takes place
- Scheduler
  - 180 Integer Registers
  - 168 Vector Registers
- There are 8 ports to the execution units
- Most execution units are duplicated to reduce wait time for micro-ops

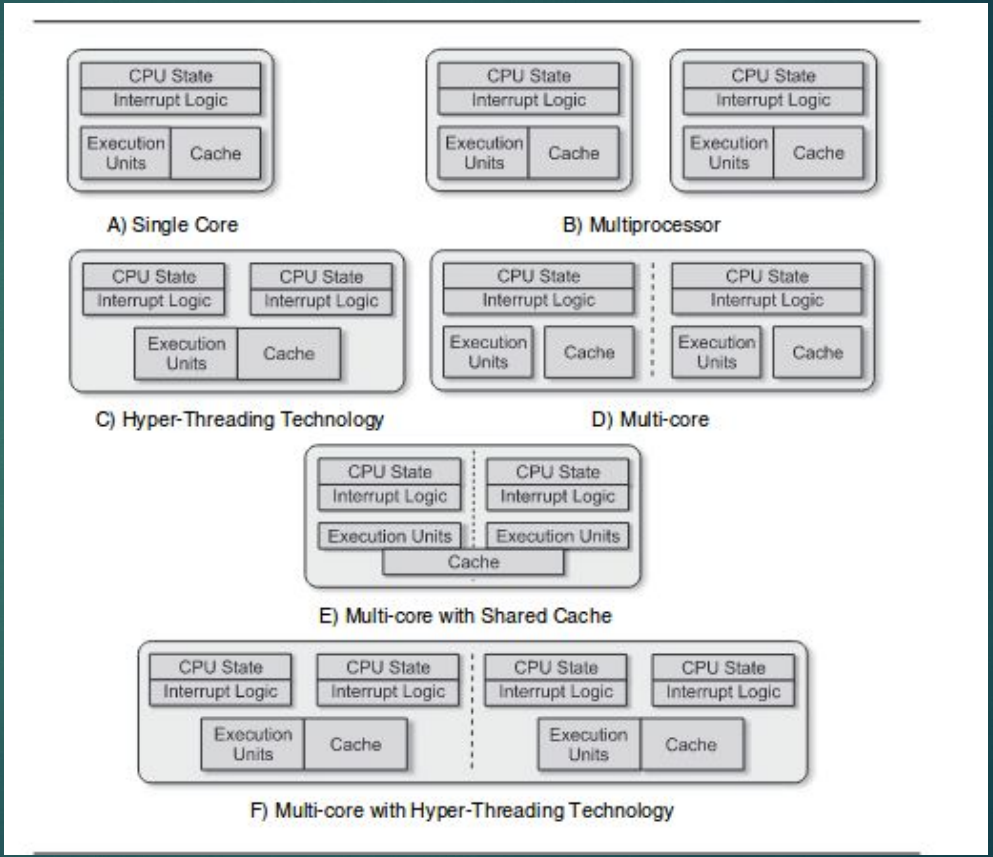
Hyper-Threading

Intel's ace in the hole

What is Hyper-Threading

- Intel name for Simultaneous Multithreading
  - 2 Hardware Thread Contexts per Core
- 2 Threads - 1 Core
  - Shared Resources
    - L1 and L2 Cache
    - ALU
    - Execution Units
  - Not as great as having 2 cores

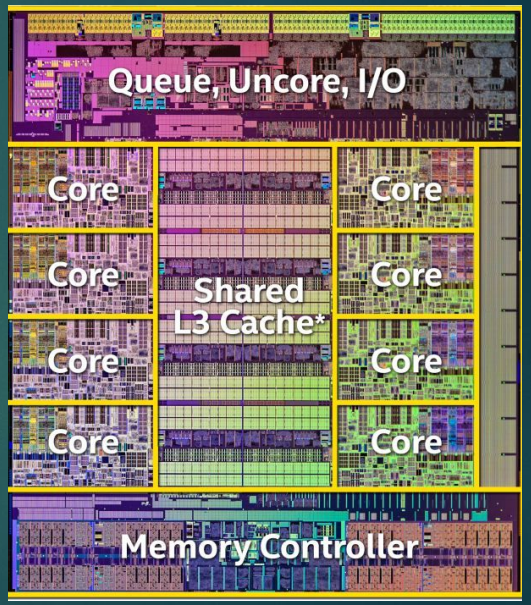
HT vs MC


CPU State
Interrupt Logic
Execution Units
Cache
A) Single Core
B) Multiprocessor
C) Hyper-Threading Technology
D) Multi-core
E) Multi-core with Shared Cache
F) Multi-core with Hyper-Threading Technology

Performance Boosts

- Surprisingly, only about 30%
  - ALU, Cache, and Physical Registers are shared
  - Adding another thread would only gives an estimated 10% increase

- More cores is more beneficial
  - Why not put more cores in then?
    - Expensive to add more space



Lemme buy a “hyper-threading” i7!

- Sure! If you want old tech or have a big wallet
  - Only 1 latest-gen i7 with HT
    - 9800X - $669 (8 Cores)

- i9 is where it’s at
  - If you want hyperthreading , buy an i9
  - i7 now has 8 cores, last gen had min 6

Conclusion

A summation of why buy the i7