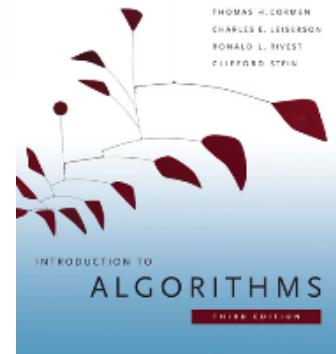


# Aamir Shafi's Profile

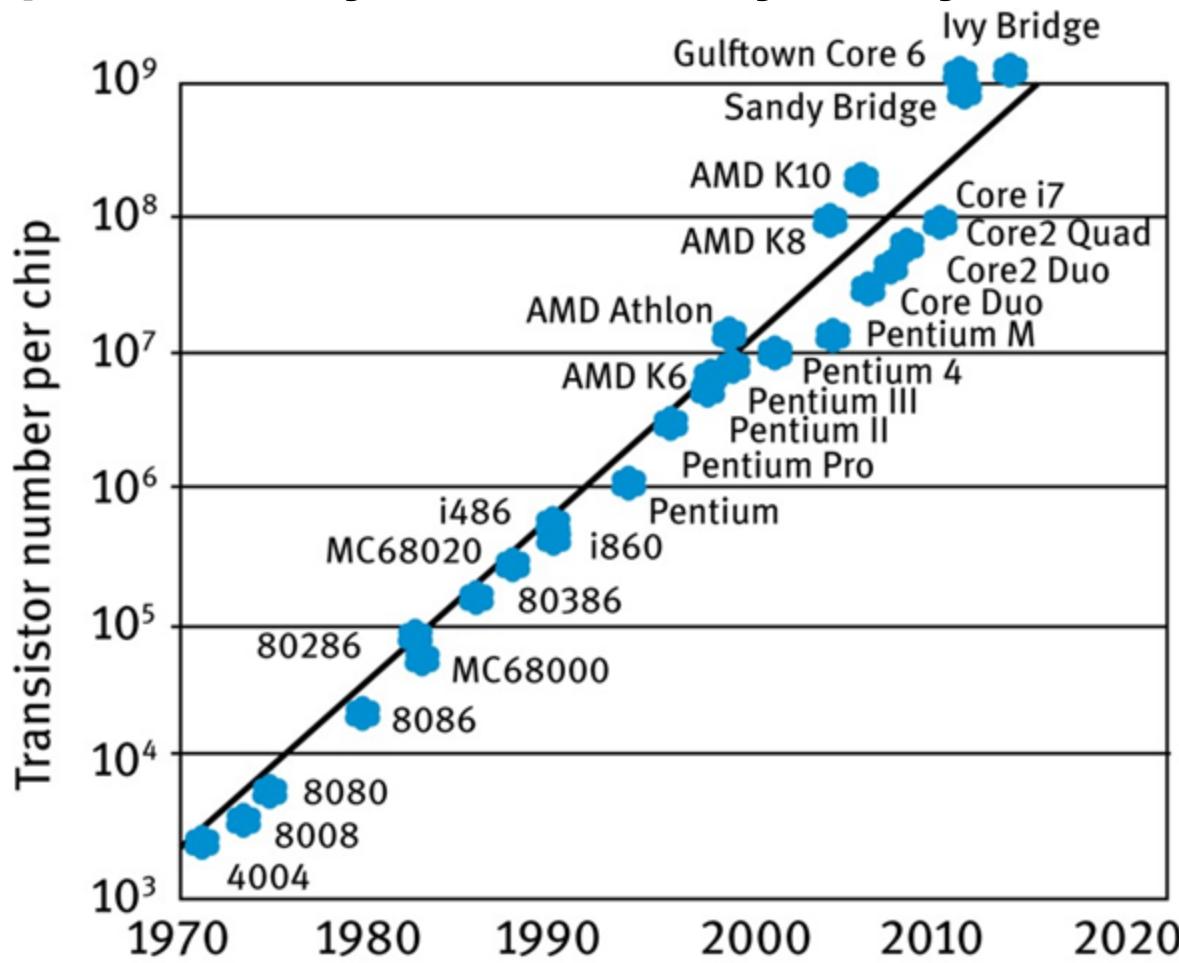


- **Background:**
  - BESE, MCS - NUST, '03
  - PhD, ICG, University of Portsmouth,
  - Post-doc, MIT, USA, '11
  - Co-founded xFlow Research, '11 – '12  
(Worked for Dell & Cavium Networks)
- Conducts R&D in the area of High Performance Computing (HPC)
- Architect/main developer of the MPJ Express software

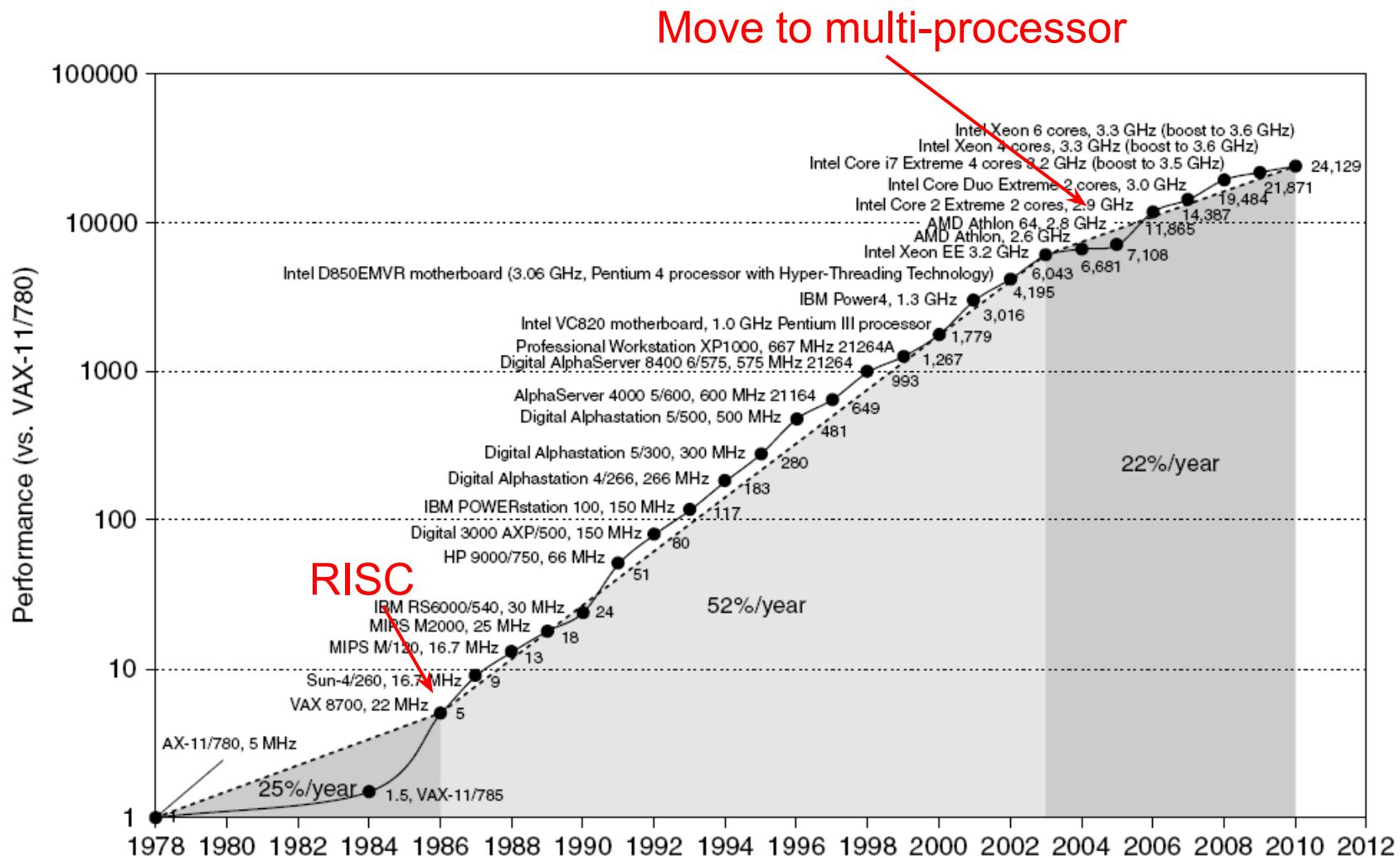


# Moore's law

- Number of transistors incorporated in a chip will approximately double every two years



# Single Processor Performance



**15:** Intel introduces 5<sup>th</sup> generation Intel® processor (**1.3 billion transistors**).



**12:** Intel introduces the Intel® Core i5 processor (**1 billion transistors**).



**001:** Intel introduces Intel® Pentium® 4 processor (**2 million transistors**).



## WHAT CAN BE DONE, CAN BE OUT

Intel continues to deliver on the promise of Moore's Law through the introduction of powerful multi-core technologies, transistor architecture, advances in materials science and new innovation.

**2004:** Intel introduces Intel® Pentium® 4 processor with HT technology (**125 million transistors**).



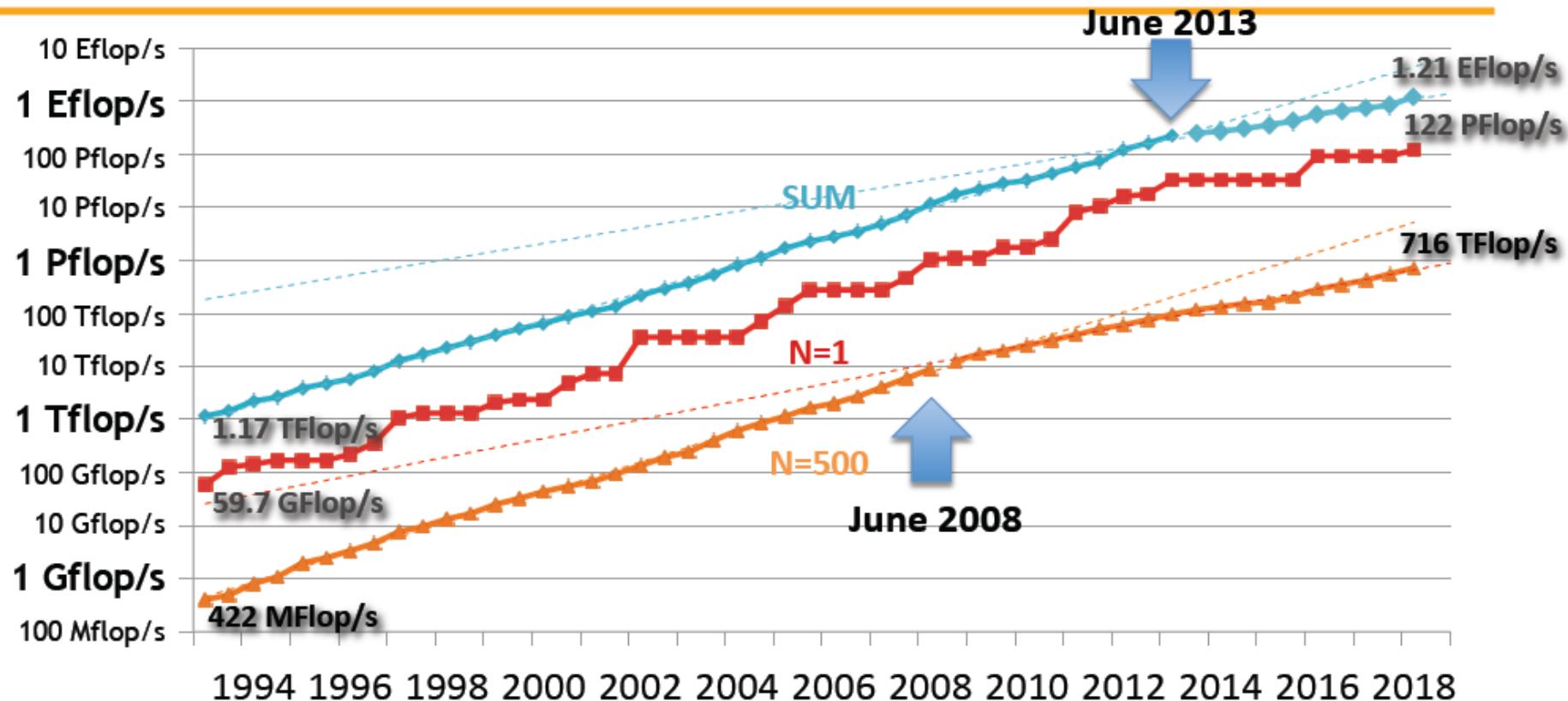
# Measuring Performance

FLOPS, Floating Point Operations per Second



Name	FLOPS
zettaFLOPS	$10^{21}$
exaFLOPS	$10^{18}$
petaFLOPS	$10^{15}$
teraFLOPS	$10^{12}$
gigaFLOPS	$10^9$
megaFLOPS	$10^6$
kiloFLOPS	$10^3$
FLOPS	1

# Performance Development †



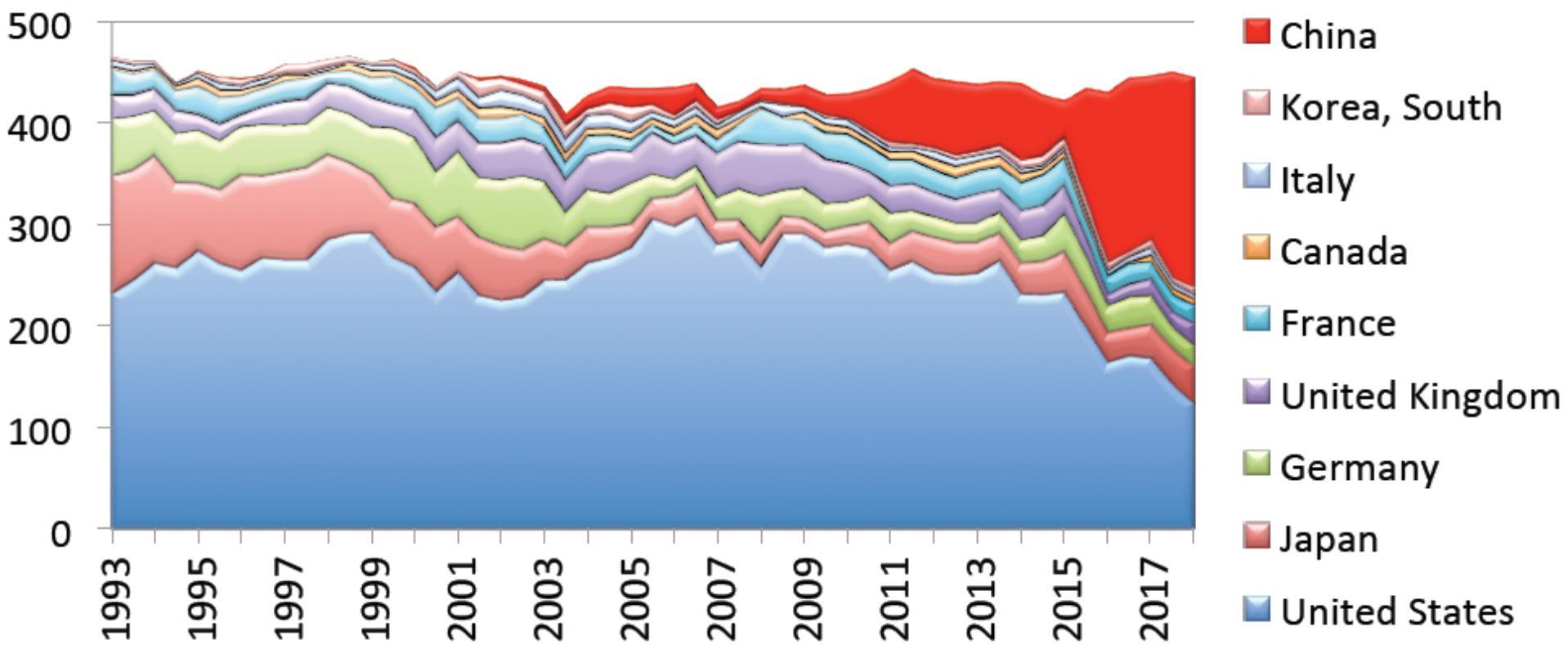
† <https://www.top500.org/static/media/uploads/>

# Countries †

The rise of China!

China: 0.4% (2) in 2000 → 45.5% (227) in 2018

USA: 51.6% (258) in 2000 → 24.8% (124) in 2018



# TOP5 Supercomputers (June '19)

#	Name	Computer	Site	Country	Total Cores	Rmax [PFlop/s]	Power (MW)
1	Summit	IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband	Oak Ridge National Laboratory	United States	2414592	148.6	10.1
2	Sierra	IBM Power System S922LC, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband	LLNL	United States	1572480	94.6	7.4
3	Sunway TaihuLight	Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway	National Supercomputing Center in Wuxi	China	1064960	93.01	15.3
4	Tianhe-2 A	TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000	National Super Computer Center in Guangzhou	China	4981760	61.44	18.4
5	Frontera	Dell C6420, Xeon Platinum 8280 28C 2.7GHz, Mellanox InfiniBand HDR	Texas Advanced Computing Center/Univ.	United States	448448	23.51	-

# #1: IBM Summit



# #3: Sunway TaihuLight



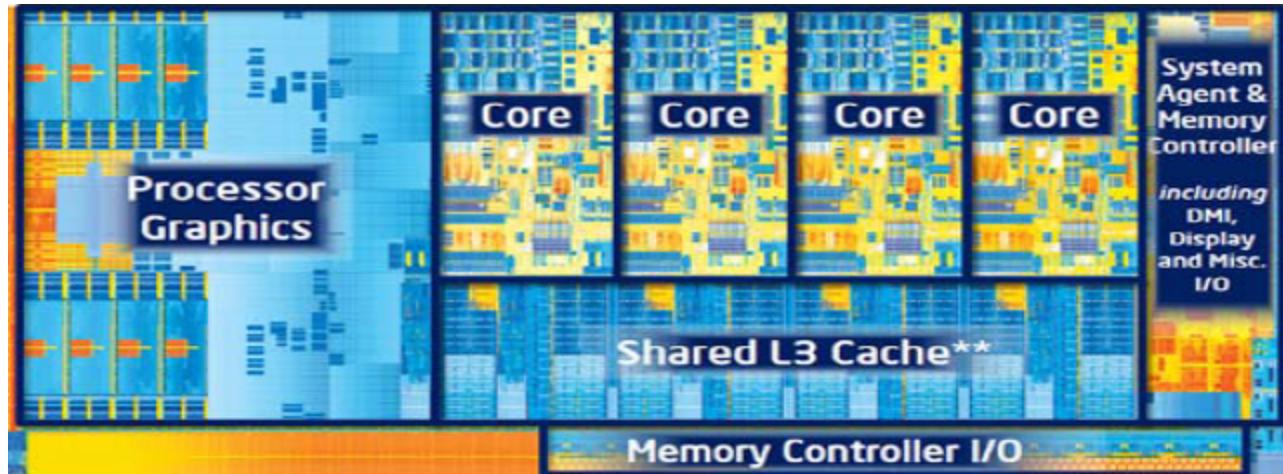
# What helps Performance?

- **Clock Speed**
- **In a clock cycle, can do more work -- since transistors are faster, transistors are more energy-efficient, and there's more of them**
- **Better architectures: finding more parallelism in one thread, better branch prediction, better cache policies, better memory organizations, more thread-level parallelism, etc.**

# Modern Trends

- **Clock speed improvements are slowing**
  - power constraints
- **Difficult to further optimize a single core for performance**
- **Multi-cores: each new processor generation will accommodate more cores**
- **Need better programming models and efficient execution for multi-threaded applications**
- **Need better memory hierarchies**
- **Need greater energy efficiency**

# Intel® Core™ i7-3770T Processor



# of Cores	4	Lithography	22 nm
# of Threads	8	Max TDP	45 W
Clock Speed	2.5 GHz	Recomm. Customer Price	TRAY: \$294.00
Max Turbo Frequency	3.7 GHz	Max Memory Size	32 GB
Intel® Smart Cache	8 MB	Memory Types	DDR3-1333/1600
Instruction Set	64-bit	# of Memory Channels	2
Instruction Set Extensions	SSE4.1/4.2, AVX	Max Memory Bandwidth	25.6 GB/s
Embedded Options Available	No		

# What is Computer Architecture?

Computer Architecture =

Instruction Set

Architecture +

Machine Organization (e.g.,  
Pipelining, Memory Hierarchy,  
Storage systems, etc) +  
Hardware implementation