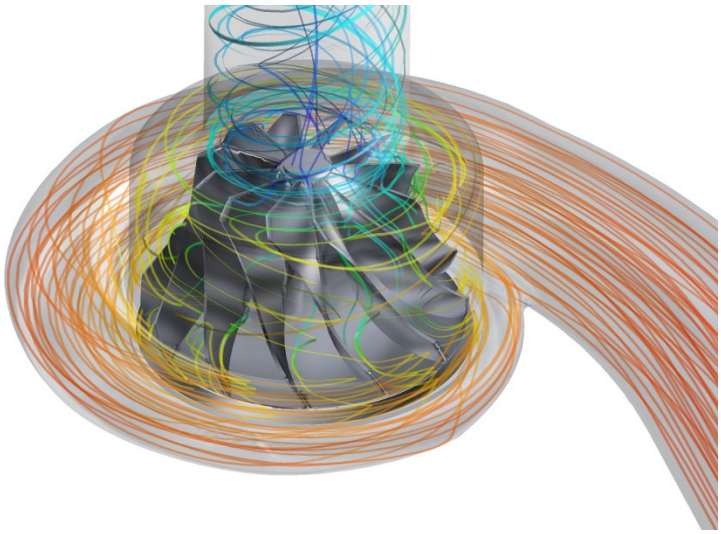
COMPUTATIONAL FLUID DYNAMICS

Ansys® CFX® Performance with AMD EPYC™ 7003 Series Processors

APRIL 2021

AMD EPYC™ 7003 Processors

AMD EPYC 7003 Series Processors are the new standard for the modern data center. With high frequencies, high core-counts, high memory bandwidth and capacity, and up to 256MB of L3 cache, AMD EPYC 7003 processors enable exceptional HPC performance. Built on the x86 architecture innovations of the record setting EPYC 7002 series processors[1], EPYC 7003 processors carry on the tradition of balanced performance.



Along with the high memory bandwidth achieved with support for 8 channels of DDR4-3200 memory, EPYC 7003 processors also synchronize the data fabric clock to match the memory clock speeds, further improving both memory bandwidth and latency. Support for up to 4TB of memory per socket enhances the ability to handle very large datasets.

Extra large caches, reaching up to 256MB per CPU and up to 32MB per core, help to efficiently utilize up to 64 cores per CPU. The large caches drive performance, but also enable exceptional scalability on many key workloads. The 128-160 lanes of PCIe® Gen4 offered by EPYC 7003 Series CPUs push the ability to efficiently access high-speed network interface cards, high-speed storage, and multiple accelerators.

AMD EPYC 7003 Series Processors are designed to bring faster time-to-value by delivering performance and scalability, while also helping to keep your data secure. AMD Infinity Guard[2] helps your organization take control of security and decrease risks to your most important assets – your data.

EPYC 7003 Series processors raise the bar once more for workload performance, helping to drive faster time to results for delivering improved business outcomes. Speed is the new metric for efficiency.

AMD EPYC 7003 FOR HPC

Gen 3 EPYC Processors help HPC workloads scale across on-premise clusters and bring HPC-level performance to the cloud for time-sensitive projects.

Check with your cloud provider about their AMD EPYC based cloud instances and ask them about helping to secure your workload in the cloud with encrypted memory.

"ZEN 3" CORE & SECURITY

Support for up to:

- 64 physical cores, 128 threads
- 256MB of L3 cache per CPU
- 32 MB of L3 cache per core
- 4 TB of DDR4-3200 memory
- 128-160 PCIe® Gen 4 lanes

Infinity Guard security

- Secure Boot
- Encrypted memory with SME
- SEV

SCALE OUT AND SCALE UP

Scaling is critical to HPC applications. AMD EPYC 7003 series processors provide high bandwidth between nodes with support for PCIe Gen 4 enabled network devices and accelerators.

Within a node, take advantage of up to 64 cores, 8 memory channels of DDR4-3200, and up to 256 MB of L3 cache-per-CPU.

Ansys® CFX®

Collaboration between AMD and Ansys offers high peformance and scalability for Computational Fluid Dynamics (CFD) workloads. Customers across many industries can benefit from the partnership between AMD and Ansys.

EPYC 7003 SERIES ARCHITECTURE QUICK LOOK

The AMD EPYC 7003 Series processor retains the proven Multi-Chip Module (MCM) Chiplet Architecture of prior successful AMD EPYC server-class processors while making further improvements. One of the most important upgrades is the new "Zen 3" core. The "Zen 3" core is manufactured using a 7nm process and designed to provide a significant instructions per cycle (IPC) uplift over prior generation "Zen 2" cores. Like EPYC 7002 Series processors, each core supports Simultaneous Multi-Threading (SMT), allowing up to 2 threads per core. In a typical 2-socket system with 64-core processors, EPYC 7003 Series processors offer up to 128 physical cores per system and up to 256 threads per system.

The L3 cache was also improved in the Gen 3 EPYC processors. EPYC 7003 Series CPUs took the same total L3 cache as the prior generation (up to 256MB/CPU) and created significantly more cache sharing between cores. The Gen 3 EPYC processors now offer a unified 32MB of L3 cache per compute die. Up to 8 cores per compute die can now share 32MB of unified L3 cache with this generation of processors.

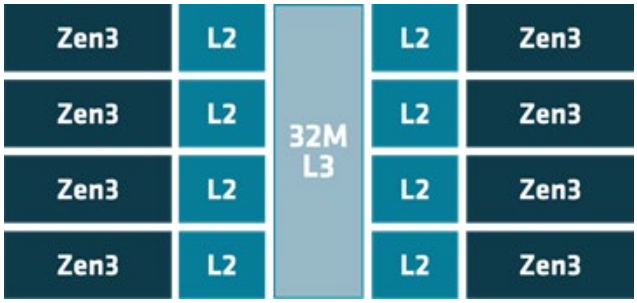


Figure 1 EPYC 7003 Series Processor L3 Cache Layout

The new L3 Cache design can increase the cache hit to miss ratio over the previous design. Improved cache sharing also allows larger blocks to fit directly into the cache whereas previously they would fall into the main memory. Improvements made in the cache fetching and eviction policies manage data more efficiently. All these benefits result in an uplift on HPC workloads in addition to the core and memory improvements.

EPYC 7003 Series CPU Options and Recommendations by Segment

AMD EPYC 7003 Series CPUs offer 19 different CPU configurations. Below is a table of each CPU with a summary of their features. For driving up per-core performance, pay special attention the 7xF3 processors, which offer the highest cache and frequencies at their respective core-counts of the EPYC 7003 series processors.

HPC applications come in a wide range of unique characteristics. There is no one-size fits all CPU for the HPC market. Below are the general recommendations. You are encouraged to talk to your AMD sales representative for more detailed guidance and CPU suggestions based on your unique environment and needs.

Model	# CCDs	Cores / Threads	Base Freq (GHz)	Max Boost Freq (Up to GHz)[3]	Default TDP (W)	cTDP (W)	L3 Cache (MB)	NPS	2P/1P
7763	8	64 / 128	2.45	3.50	280W	225-280W	256	1,2,4	2P/1P
7713	8	64 / 128	2.00	3.675	225W	225-240W	256	1,2,4	2P/1P
7713P								1,2,4	1P
7663	8	56 / 112	2.0	3.5	240W	225-240W	256	1,2,4	2P/1P
7643	8	48 / 96	2.3	3.6	225W	225-240W	256	1,2,4	2P/1P
75F3	8	32 / 64	2.95	4.0	280W	225-280W	256	1,2,4	2P/1P
7543	8	32 / 64	2.8	3.7	225W	225-240W	256	1,2,4	2P/1P
7543P								1,2,4	1P
7513	4	32 / 64	2.6	3.65	200W	165-200W	128	1,2,4	2P/1P
74F3	8	24 / 48	3.2	4.0	240W	225-240W	256	1,2,4	2P/1P
7453	4	28 / 56	2.75	3.45	225W	225-240W	64	1,2,4	2P/1P
7443	4	24 / 48	2.85	4.0	200W	165-200W	128	1,2,4	2P/1P
7443P								1,2,4	1P
7413	4	24 / 48	2.65	3.6	180W	165-200W	128	1,2,4	2P/1P
73F3	8	16/ 32	3.5	4.0	240W	225-240W	256	1,2,4	2P/1P
7343	4	16 / 32	3.2	3.9	190W	165-200W	128	1,2,4	2P/1P
7313	4	16 / 32	3.0	3.7	155W	155-180W	128	1,2,4	2P/1P
7313P								1,2,4	1P
72F3	8	8 / 16	3.7	4.1	180W	165-200W	256	1,2,4	2P/1P

Table 1 AMD EPYC 7003 CPU Options

Listed in the table below are a few examples of different HPC market segments, a general sense of the characteristics and sensitivities of applications per segment, and specific AMD EPYC 7003 Series processor recommendations per segment.

Segment	Sensitivity	Example Applications	Recommended Models	Comments
FEA Explicit	Frequency & Cache	LS-DYNA	75F3 | 7543 74F3 | 73F3	Look for CPUs with high frequencies, and large caches. Mid core-counts help increase performance per core to help maximize software investment.
FEA Implicit		Mechanical		
CFD	Memory BW & Cache	Fluent, CFX	75F3 | 7543 74F3	Look for CPUs with 256 MB of cache. Large caches help relieve the potential memory bandwidth bottleneck if using high core counts. Look for mid core-count CPUs for per-core licensed codes.
EDA	Frequency & Cache	RedHawk	73F3 | 72F3	This market segment is dominated by low core-counts to drive up the frequency and cache per core, helping maximize software investment.

Table 2 HPC Segment Recommendations

Ansys CFX

Ansys CFX is a high-performance computational fluid dynamics (CFD) software tool that delivers robust, reliable, and accurate solutions quickly across a wide range of CFD and Multiphysics applications. CFX is recognized for its outstanding accuracy, robustness, and speed when simulating turbomachinery, such as pumps, fans, compressors, and gas and hydraulic turbines. AMD and Ansys have an ongoing collaboration to deliver exceptional performance for customers.

Test Methodology

This document focuses on performance and scaling of the EPYC 7003 Series processors as well as comparison with the Intel® Xeon® Gold 6258R.

Testing was performed on dual-socket AMD EPYC™ 7413, AMD EPYC™ 74F3, AMD EPYC™ 7543, and AMD EPYC™ 75F3-based systems. The compute nodes were each populated with 1 DIMM per channel of 64GB, dual-rank, DDR4-3200 DIMMs from Micron®, for a total of 1TB of memory per node. A Mellanox® ConnectX-6 200 Gb/s HDR InfiniBand adapter, utilizing EPYC processors' support for PCIe Gen 4, is also populated on each EPYC processor-based system.

Testing was also run on a single-node dual-socket Intel® Xeon® 6258R-based platform. The 6258R was selected because it offers the highest frequency of the highest core-count (28c) in the Intel Xeon Gold family of processors. The Intel platform was populated with 1 DIMM per channel of 64GB, dual-rank, DDR4-2933 DIMMS (768GB total memory), matching the maximum memory speed supported for this processor.

Ansys provides a standard set of benchmarks for the purpose of evaluating performance of different platforms running CFX. The benchmark cases represent typical usage and cover a range of sizes.

Performance metrics of the CFX benchmarks are reported out as elapsed time to completion. This metric follows best practices for comparing performance between different platforms and is the basis for all data and charts in this brief.

The following benchmarks have been used:

Automotive Pump

LeMans Car

Airfoil 10M

Airfoil 50M

Airfoil 100M

Every benchmark was run a minimum of 3 iterations, with the average of the performance results used in the brief. Results of each benchmark were also confirmed to have <1% variability between all runs.

System Configuration

AMD System Configuration				
CPUs	2 x AMD EPYC 7413	2 x AMD EPYC 74F3	2 x AMD EPYC 7543	2 x AMD EPYC 75F3
Frequency: Base | Boost[3]	2.65GHz | up to 3.6GHz	3.2GHz | up to 4.0GHz	2.8GHz | up to 3.7GHz	2.95GHz | up to 4.0GHz
Cores	24 cores/socket (48c/node)		32 cores/socket (64 per node)	
L3 Cache	128 MB	256MB		
Memory	1TB (16x) Dual-Rank DDR4-3200 64GB DIMMs, 1DPC			
NIC	Mellanox ConnectX-6 HDR 200Gb InfiniBand x16 (OFED-4.5-1.0.1)			
Storage: OS | Data	1 x 256 GB SATA | 1 x 1 TB NVMe			
BIOS and Settings	SMT=off, X2APIC=on, IOMMU=off, APBDIS=1, Fixed SOC P-state=0, Determinism=power, NPS=4, DF C-states=off, PIO, EPIO, TSME=off, PCIe 10 bit tag=on			
OS Settings	clear caches before every run, NUMA balancing 0, randomize_va_space 0, cc6 disabled, Governor=Performance			

Table 3 AMD EPYC System Configuration

Intel System Configuration	
CPUs	2 x Intel Xeon Gold 6258R
Frequency: Base | Turbo	2.7GHz | 4.0GHz
Cores	28 cores per socket (56 per node)
L3 Cache	38.5MB
Memory	768 GB (12x) Dual-Rank DDR4-2933 64GB DIMMs, 1DPC
NIC	Mellanox ConnectX-6 HDR 200Gb InfiniBand x16 (OFED-4.5-1.0.1)
Storage: OS | Data	1 x 256 GB SATA | 1 x 1 TB NVMe
BIOS and Settings	3.3a: Power Management=Extreme Performance, Hyper-threading=Off, SNC=On, ADDDC=Off
OS Settings	clear caches before every run, NUMA balancing 0, randomize_va_space 0

Table 4 Intel System Configuration

Software	
Solver Version	Ansys CFX 2021 R1
MPI	Intel MPI 2018
OS	SLES 12 SP 5

Table 5 Software

Ansys CFX Single-Node Performance

Single-node performance testing was performed on multiple AMD EPYC 7003 based systems and an Intel Xeon Gold 6258R based system. The chart below shows the Gen 3 AMD EPYC processor clearly outperforming the Intel Xeon Gold 6258R.

CFX performance is affected by many aspects of the CPU. Due to the EPYC processor's superior memory bandwidth and larger cache, the CFX application can scale extremely well, resulting in impressive performance in comparison to the competition.

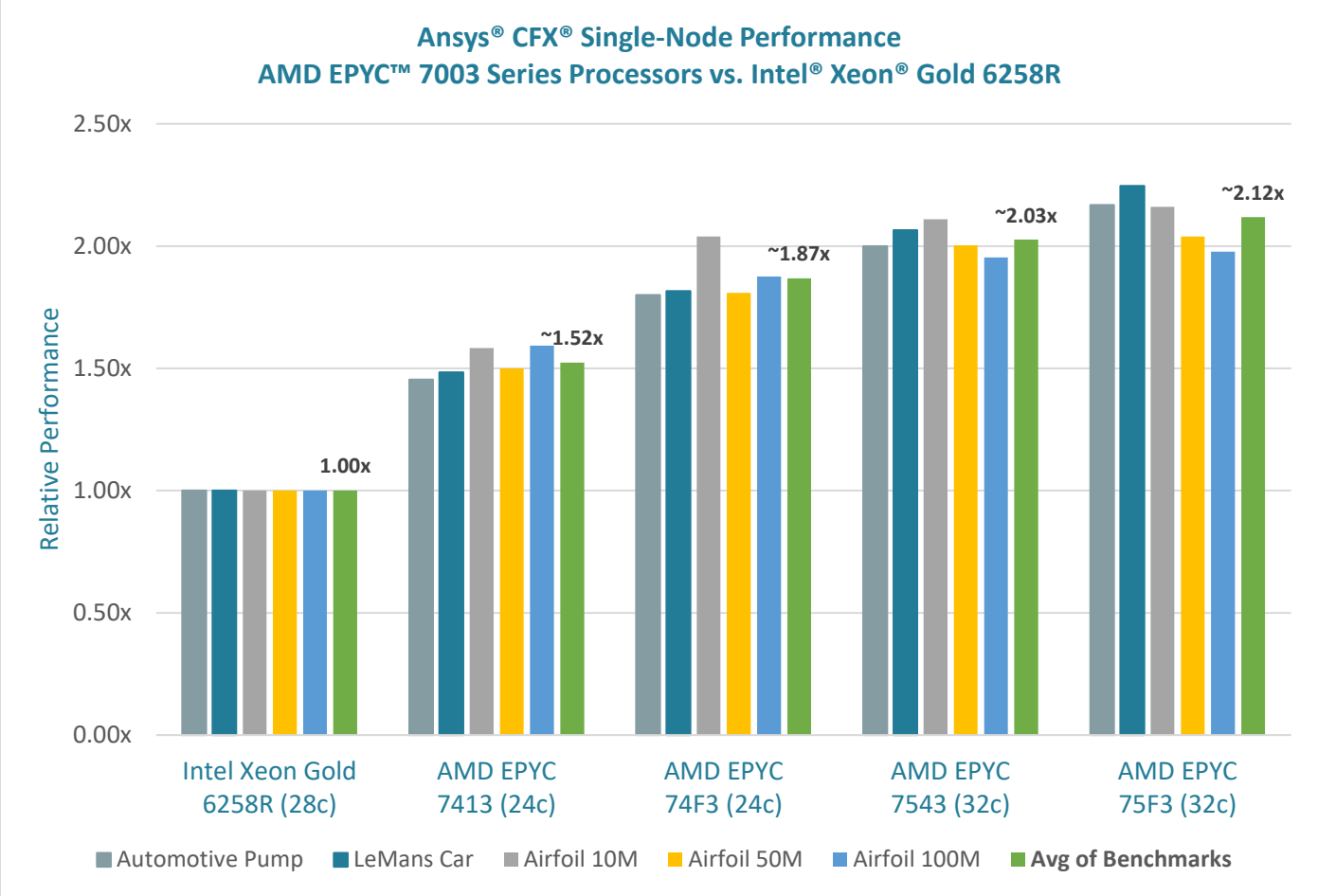


Figure 2 Ansys CFX Single-Node Performance

All AMD EPYC processors tested outperform the Intel Xeon Gold 6258R in all benchmarks. A balance of high memory bandwidth, large caches, and high frequency yields great results:

- The most performant processor tested is the 32-core AMD EPYC 75F3, base frequency 2.95GHz and max boost of up to 4.0GHz; it outperforms the Intel baseline system in all benchmarks by an average of up to 2.12x.
- The 32-core 7543 shows great performance with a base frequency of 2.8GHz and a max boost of up to 3.7GHz. The large cache (the same 256MB total cache as the 75F3), helps keep the performance very high.
- The 24-core AMD EPYC 74F3, with an even higher base frequency than the 75F3 (3.2GHz base and max boost of up to 4.0GHz), maintains an average uplift of up to 1.87x, despite having 4 fewer cores than the 6258R.
- With lower base (2.65GHz) and max boost (up to 3.6GHz) frequencies, the 24-core AMD EPYC 7413 still outperforms the 28-core Intel Xeon Gold 6258R on the benchmark suite by an average of up to 1.52x.

Ansys CFX Performance Per Core

Understanding workload performance at the core level provides a better understanding of the potential TCO of a hardware purchase:

- *Maximize Software Investment*: Many software vendors, including Ansys, offer per-core software licensing. It may be beneficial, depending on your specific situation, to maximize performance per-core to help minimize your TCO. Understanding how performance relates to core counts helps right-size how many licenses are required and enables running simulations at higher fidelity.
- *Precise Installation Sizing*: Core-level performance makes it easier to fine-tune decision-making when sizing the application footprint of your hardware purchase.

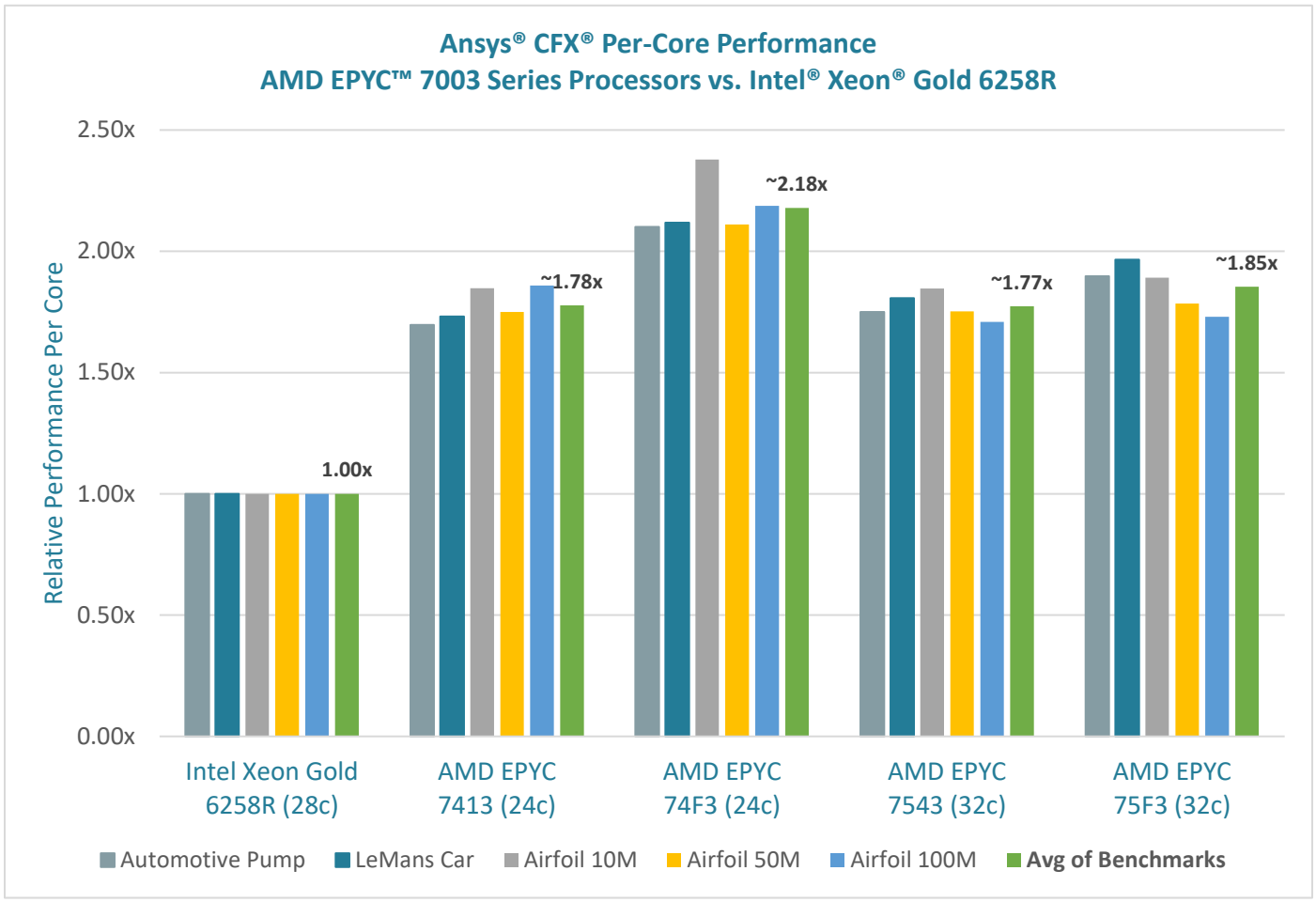


Figure 3 Ansys CFX Per-Core Performance

All AMD EPYC 7003 Series processors tested deliver truly exceptional per-core performance:

- The lower frequency, lower cache 24-core EPYC 7413 (128MB L3 Cache) still delivers dominant per-core performance, with an average uplift of up to 1.78x over the Intel Xeon 6258R.
- The 24-core EPYC 74F3 stands out, delivering on average up to 2.18x the performance per core vs. the Intel Xeon Gold 6258R.
- With lower cache per core compared to the EPYC 74F3 processor, both 32 core EPYC processors also outperform Intel Xeon 6258R baseline on a per-core performance basis.

Ansys CFX Multi-Node Scaling

CFX scales exceptionally well on AMD EPYC 7003 series processors in a multi node scenario. The chart below shows scaling of the AMD EPYC 75F3 CPU in two-socket platforms vs. linear scaling running the Airfoil 10M, 50M, 100M benchmarks. At 32-cores per processor, each node has 64 physical cores for a total of 256 cores at 4 nodes.

CFX exhibits very good scaling. At 2 nodes (128 cores), the speedup is essentially perfect. At 4-8 nodes (256 cores – 512 cores), the speedup stays very high at with the lowest being the smaller benchmark Airfoil 10M at ~6.99.

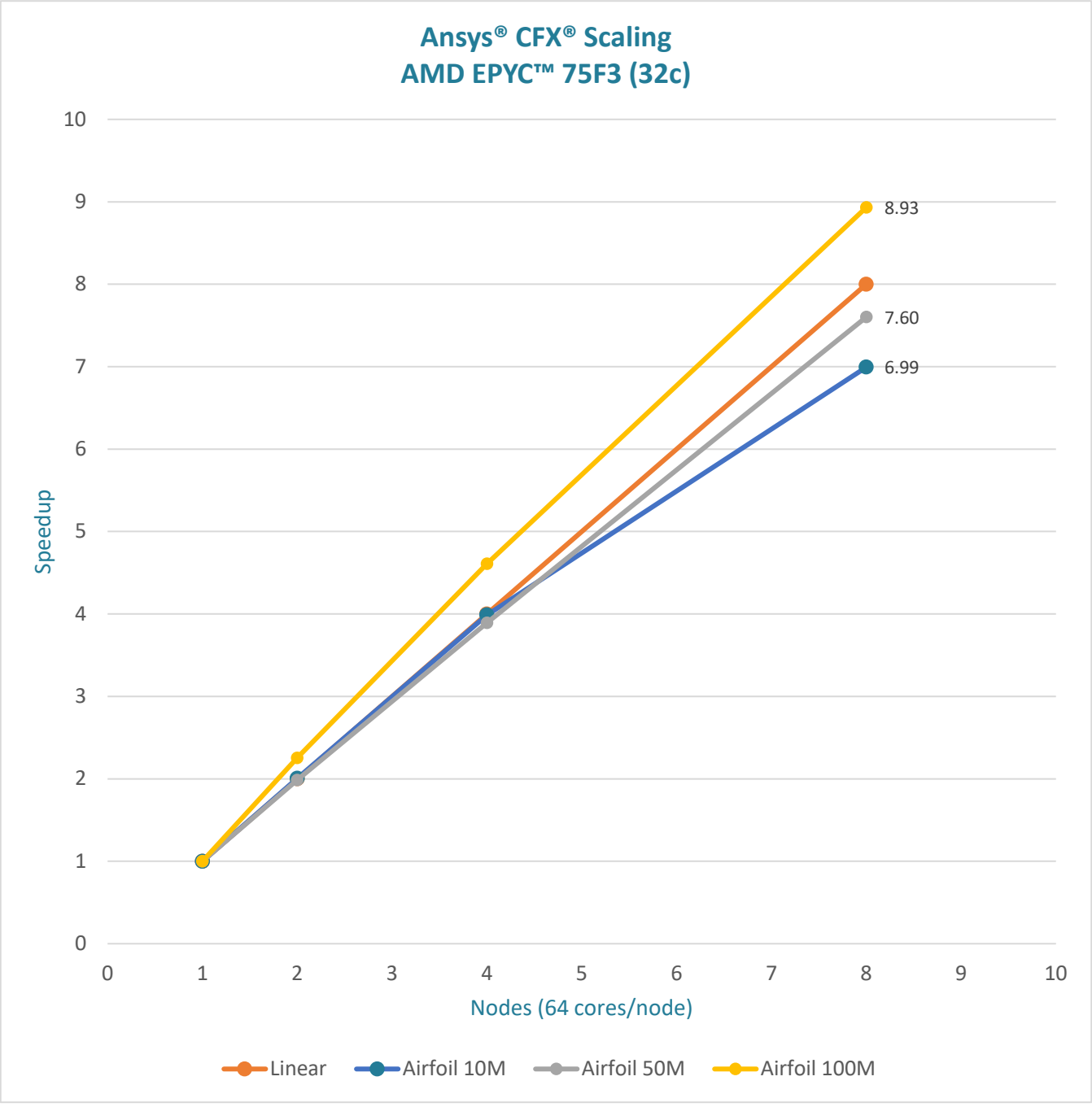


Figure 4 Ansys CFX Multi-Node Scaling

Conclusion and Recommendations

The results from running multiple Ansys CFX benchmarks on a variety of AMD EPYC 7003 series processors have been presented and analyzed in comparison with the Intel Xeon Gold 6258R.

Single and multi-node scaling results have shown overall performance dominance for all AMD processors tested as compared to the Intel Xeon Gold 6258R.

- All AMD EPYC processors tested outperformed the Intel baseline system by an average of approximately1.52x.
- The 32-core high frequency AMD EPYC 75F3 is the overall performance leader with an average uplift of up to 2.12x and an average per-core performance advantage of up to 1.85x.
- The 24-core high frequency AMD EPYC 74F3 maintains an average per-node uplift of up to 1.87x and an average per-core performance advantage of up to 2.18x.

Whether you are scaling-out to higher node-counts, or driving more density into your clusters, AMD EPYC 7003 Series processors give you more levers to tilt the performance balance to your advantage.

RELATED LINKS

- Ansys*
- Ansys and AMD*
- Ansys CFX*
- High Performance Computing (HPC) Tuning Guide for AMD EPYC™ 7003 Series Processors
- AMD EPYC™ Processors
- AMD EPYC Technical Briefs and Tuning Guides

*Links to third party sites are provided for convenience and unless explicitly stated, AMD is not responsible for the contents of such linked sites and no endorsement is implied.

FOOTNOTES

1. For a complete list of world records see http://amd.com/worldrecords. EPYC-22
2. AMD Infinity Guard features vary by EPYC™ Processor generations. Infinity Guard security features must be enabled by server OEMs and/or Cloud Service Providers to operate. Check with your OEM or provider to confirm support of these features. Learn more about Infinity Guard at https://www.amd.com/en/technologies/infinity-guard . GD-183
3. For AMD EPYC processors is the maximum frequency achievable by any single core on the processor under normal operating conditions for server systems. EPYC-18