COMPUTATIONAL FLUID DYNAMICS

Altair AcuSolve™ Performance with AMD EPYC™ 7003 Series Processors

MARCH 2021

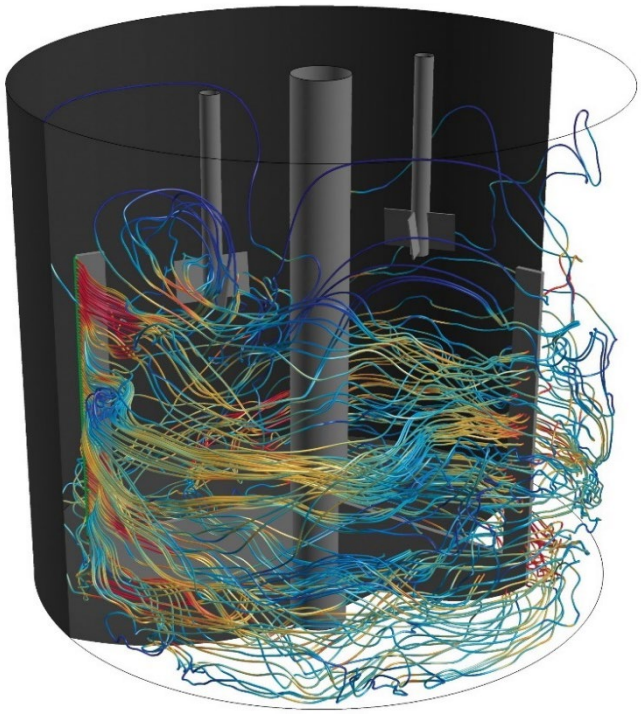
AMD EPYC 7003 Processors

Built on the x86 architecture innovations of the record setting EPYC 7002 processors[1], 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 32MB of L3 cache per core, AMD EPYC 7003 processors enable exceptional HPC performance across multiple industry verticals.

Balance is critical when driving HPC performance. Gen 3 EPYC CPUs achieve that balance by pushing performance in several areas. Along with the high memory bandwidth achieved with 8 channels of DDR4-3200 memory, EPYC 7003 CPUs 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 efficiently utilize very large datasets.

Data access is further enhanced with extra-large caches, reaching up to 256MB per CPU. All of this helps enable the ability to efficiently utilize up to 64 cores per CPU. The 128-160 lanes of PCIe® Gen4 offered by EPYC 7003 Series CPUs pushes the ability to efficiently access high-speed network interface cards, high-speed storage, and multiple accelerators.

EPYC 7003 Series processors raise the bar once more for workload performance, helping to drive faster time to results, and to provide more and better data for delivering better decisions and better outcomes. Time is the new metric for efficiency.



AMD EPYC 7003 FOR HPC

3rd Generation 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[2] security
- **Secure Boot**
- **SME**
- **SEV-SNP**

SCALE OUT AND SCALE UP

Scaling is critical to HPC applications. AMD EPYC 7003 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.

Altair AcuSolve

Altair AcuSolve™ is a proven asset for companies looking to explore designs by applying a full range of flow, heat transfer, turbulence, and non-Newtonian material analysis capabilities without the difficulties associated with traditional CFD applications.

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 EPYC Gen 3 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 EPYC Gen 3 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.

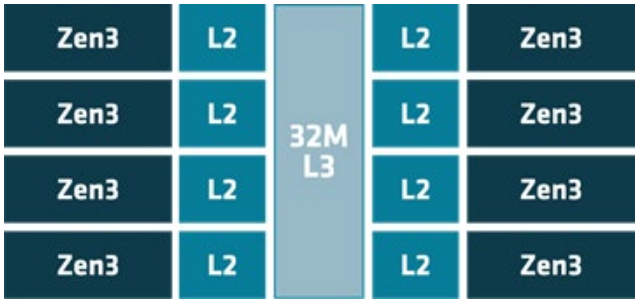


Figure 1 7003 Processor L3 Cache layout

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 it 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 series of processors, which offer the highest cache and frequencies at their respective core-counts of the 7003 series processors.

Model	# CCDs	Cores / Threads	Base Freq (GHz)	Max Boost Freq (GHz)	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 CPU Options

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

The table below lists 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	Radioss	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		OptiStruct		
Molecular Dynamics	Core Count & Frequency	GROMACS, LAMMPS	7763 | 7713 7663 | 7643 75F3 | 7543	Look for CPUs with high core-counts and frequency. These applications scale very well with cores.
Weather	Memory BW & Cache	WRF, IFS	7763 | 7713 7663 | 7643 75F3 | 7543 74F3	Look for CPUs with 256MB 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.
CFD		AcuSolve		
Oil & Gas		Reveal, Echos, SAVA		
EDA	Frequency & Cache	VCS, 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

Altair AcuSolve

For an analyst performing advanced computational fluid dynamics (CFD) modeling, or a design engineer quickly needing to understand fluid or thermal effects on a design proposal, Altair offers a complete set of tools to support each project. From detailed component analysis to full systems performance, Altair provides a range of scalable solvers and robust pre- and post-processing software for CFD.

Altair AcuSolve™ is a proven asset for companies looking to explore designs by applying a full range of flow, heat transfer, turbulence, and non-Newtonian material analysis capabilities without the difficulties associated with traditional CFD applications. AcuSolve™ is robust, scalable, and accurate regardless of the quality and topology of the mesh elements. No CFD software gets you to your end goal sooner: analyzing results and exploring the physics of products.

Test Methodology

This document focuses on performance and scaling of the AMD EPYC 7003 Series Processors as well as competitiveness with the Intel Xeon 6258R.

Testing was performed on a dual-socket AMD EPYC™ 74F3, AMD EPYC™ 7543, and AMD EPYC™ 75F3-based systems. The compute nodes were populated with Micron® 1 DIMM per channel of 64GB, dual-rank, DDR4-3200 DIMMs, 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 performed on a 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.

AcuSolve uses a standard set of computational fluid dynamics simulation models to measure performance. These models are specifically created to reflect real-world workloads to give a standard basis of comparison across various computer systems and architectures. The single node tests in this document are using the impinging nozzle model.

AcuSolve performance is typically measured in elapsed time. To show relative performance comparisons, we convert elapsed time to performance (1/elapsed time), then show the relative comparison (AMD Perf/Intel Perf, higher is better).

Every benchmark was run a minimum of 3 iterations, with the average of the performance results used in this 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 74F3	2 x AMD EPYC 7543	2 x AMD EPYC 75F3
Frequency: Base | Boost[3]	3.2GHz | 4.0GHz (up to)	2.8GHz | 3.7GHz (up to)	2.95GHz | 4.0GHz (up to)
Cores	24 cores/socket (48c/node)	32 cores/socket (64c/node)	
L3 Cache	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 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	768GB (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	Altair AcuSolve 2021
MPI	Intel MPI 2019
OS	RHEL 8.3

Table 5 Software

Altair AcuSolve Single-Node Performance

Single-node performance is a critical starting point for evaluating a cluster performance. In this section we compare single-node relative performance of a large-scale steady-state implicit incompressible flow simulation, where a stiff sparse linear system is solved repeatedly.

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

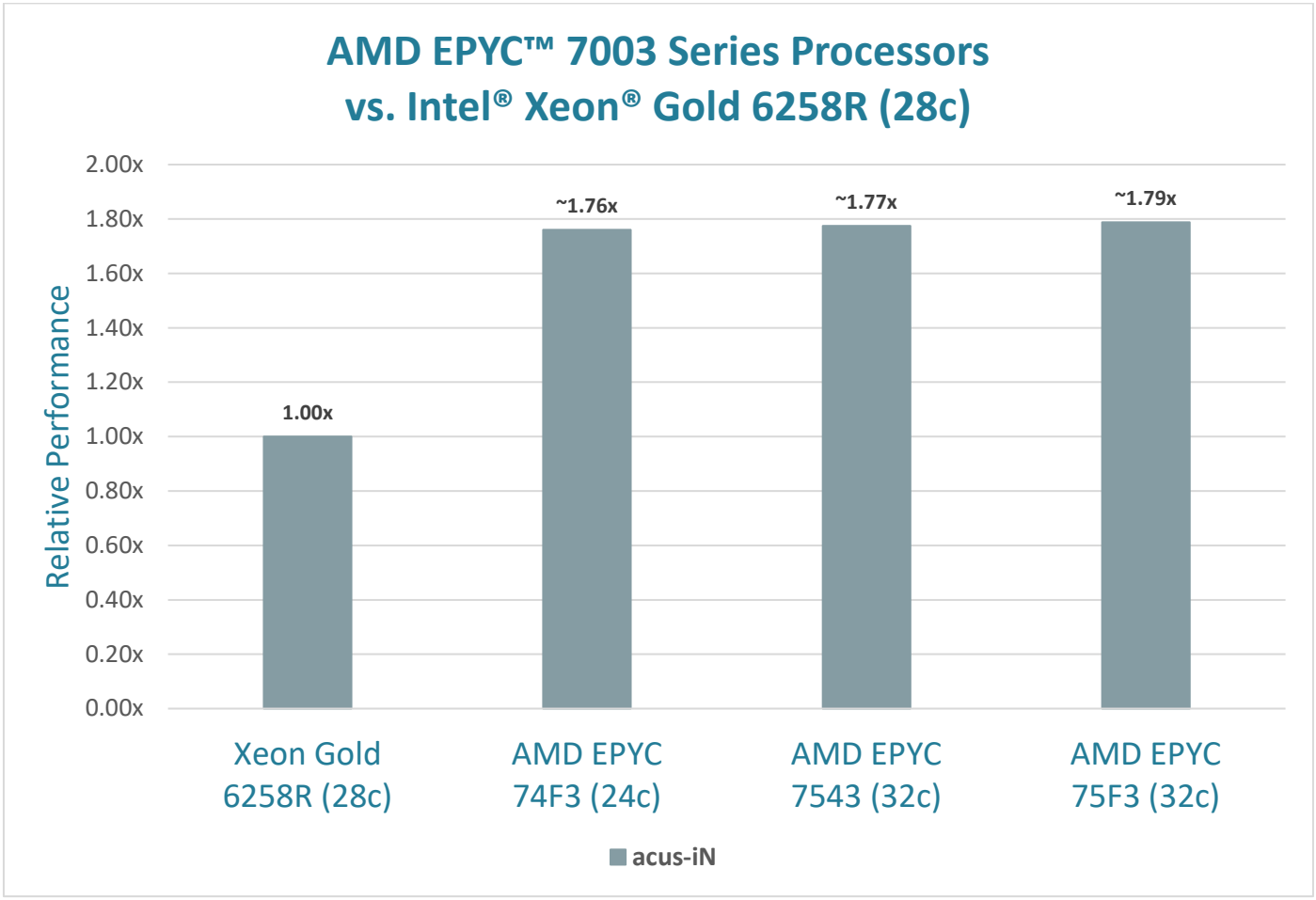


Figure 1 Altair AcuSolve Single-Node Performance

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:

- We can see in the chart above that all AMD EPYC 7003 series processors perform similarly and outperform the Intel Xeon Gold 6258R. The reason for this is because of how much the workload is memory bandwidth bound. We are bound by memory bandwidth at 24 cores so adding more cores is not yielding more performance.
- If you are using your system exclusively for AcuSolve, and running memory bandwidth bound workloads, it may not be beneficial to get a larger core count processor; however, if you have a multipurpose cluster where other types of codes will be run, investigating higher core count processors may be beneficial.

Altair AcuSolve Per-Core Performance

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

- *Maximize Software Investment:* Many software vendors, including Altair, offer per-core software licensing. It may be beneficial to maximize performance per-core to minimize your TCO, depending on your specific situation. 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.

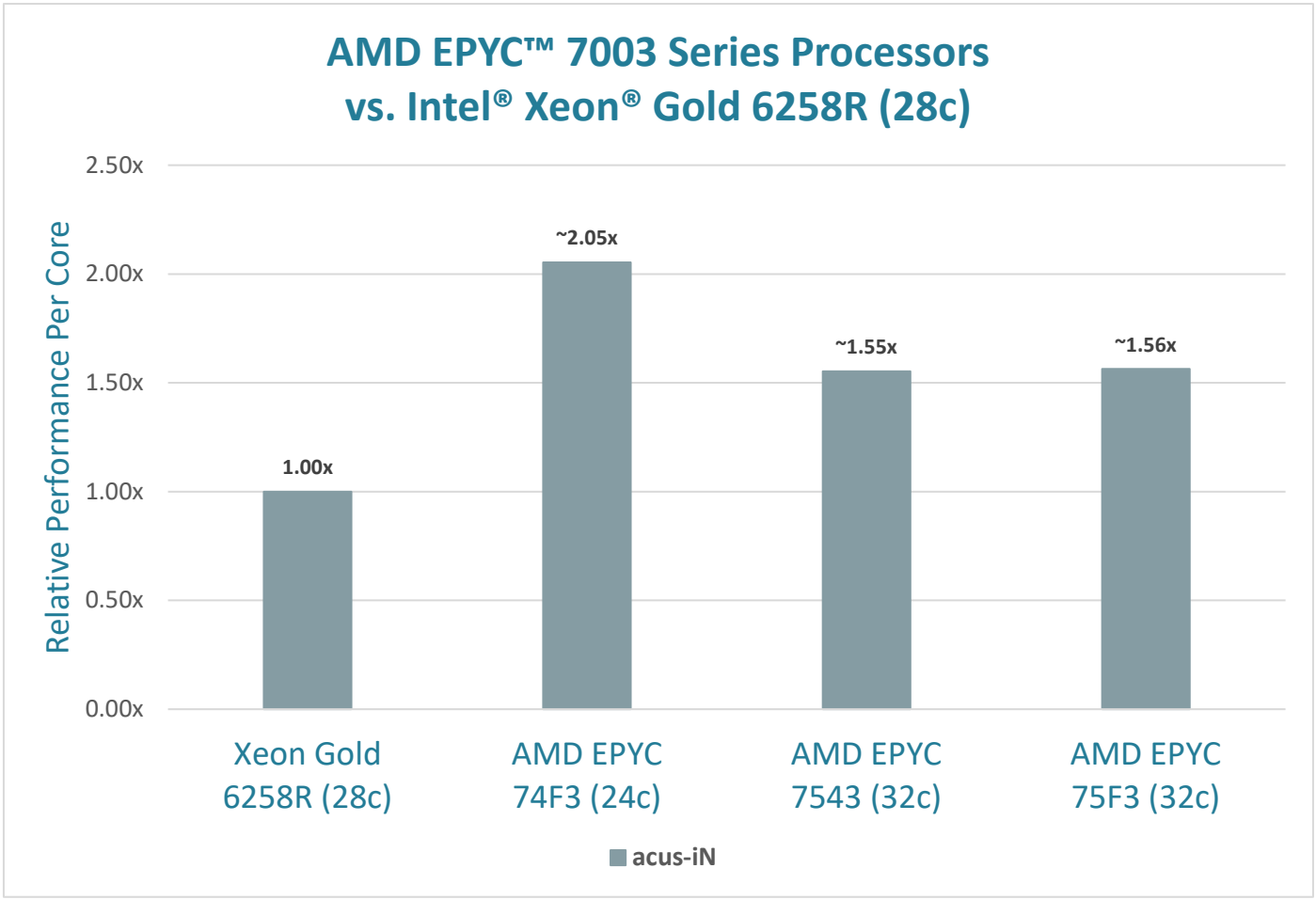


Figure 2 Altair AcuSolve Per-Core Performance

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

- The AMD EPYC 74F3 has the highest per-core performance at 2.05x that of Intel Xeon 6258R.
- The per-core performance on the 32 core AMD EPYC processors is lower due to the workload being memory bandwidth bound. Since adding more cores is not helping performance, the per-core performance drops.
- It is important to investigate the proper balance of memory bandwidth to cores to maximize the per-core performance.

Conclusion

With the launch of AMD EPYC 7003 Series processors, performance on Altair AcuSolve has taken a new leap. The new "Zen 3" core as well as new L3 cache design and improvements in the memory subsystem bring a new level of performance to the table for Computational Fluid Dynamics workloads.

We compared performance of AMD EPYC 74F3, AMD EPYC 7543 and AMD EPYC 75F3 processors against the Intel Xeon 6258R on the AcuSolve Impinging Nozzle workload. On a single node the AMD EPYC 74F3 was able to deliver up to 1.76x (~76% more) performance than the Intel Xeon 6258R. When comparing per core performance the AMD EPYC 74F3 was able to deliver up to 2.05x (~105% more) performance than the Intel Xeon 6258R.

It is critical to understand the proper balance of memory bandwidth to cores to maximize per-core performance. Too many cores and per-core performance drops and there is a potential to overpay on licensing costs. Too few cores and you run the risk of leaving performance on the table.

When comparing architectures and platforms for Altair AcuSolve simulations, rest assured that AMD EPYC 7003 series processors bring the latest technology available on the market to you to enable faster simulation times and increased efficiency.

RELATED LINKS

- Altair*
- Altair AcuSolve*
- 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*