CADENCE® SPECTRE® X PERFORMANCE UPLIFTS
LARGE SCALE VERIFICATION SIMULATION

Powered by 4th Gen AMD EPYC™ Processors with AMD 3D V-Cache™ technology

March 2024

AT A GLANCE

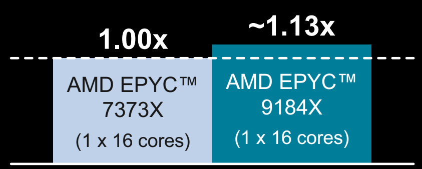
4th Gen AMD EPYC™ 9004 processors deliver exceptional generational runtime, throughput, and per-watt performance vs. prior-generation AMD EPYC 7003 processors running Cadence® Spectre® X Simulator.

PERFORMANCE HIGHLIGHTS

1P systems powered by 16, 32, and 96-core 4th Gen AMD EPYC processors show strong performance vs. comparable 3rd Gen AMD EPYC processors. These charts show composite uplifts for the 4th Gen AMD EPYC processors normalized to their 3rd Gen AMD EPYC counterparts. The detailed charts inside this brief highlight the benefits of AMD 3D V-Cache technology for both 3rd and 4th Gen AMD EPYC processors.

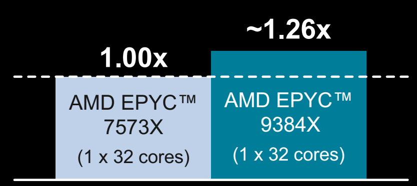
COMPOSITE RUNTIME, THROUGHPUT, & PERFORMANCE-PER-WATT UPLIFTS (16C)

SpectreMX-N5-DDRPLL-21d10d415-AllCores-NUMA



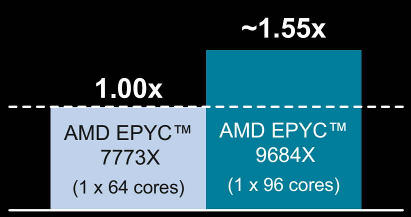
COMPOSITE RUNTIME, THROUGHPUT, & PERFORMANCE-PER-WATT UPLIFTS (32C)

SpectreMX-N5-DDRPLL-21d10d415-AllCores-NUMA



COMPOSITE RUNTIME, THROUGHPUT, & PERF-PER-WATT UPLIFTS (GP TOS)

SpectreMX-N5-DDRPLL-21d10d415-AllCores-NUMA



KEY TAKEAWAYS

Comparing 1P servers powered by a selection of 4th Gen AMD EPYC processors to their 1P 3rd Gen AMD EPYC counterparts reveals strong generational Runtime, Throughput, and Performance-per-Watt uplifts running Cadence Spectre X Simulator. Further, the 48-core AMD EPYC 9474F demonstrates excellent Performance-per-Watt. 4th Gen AMD EPYC processors with AMD 3D V-Cache™ technology are ideal for this workload because the chiplet architecture maintains performance as the system is loaded.

4th Gen AMD EPYC CPUs with AMD 3D V-Cache technology are available in 1P and 2P configurations and feature:

- Up to 1,152 MB L3 cache vs. up to 384 MB in high-frequency 4th Gen AMD EPYC processors.
- Up to 4 links of Gen 3 Infinity Fabric™ at up to 32 Gbps.
- Up to 12 memory channels that support up to 6TB of DDR5-4800 memory.
- Support for PCIe® Gen 5 at up to 32 Gbps.
- AVX-512 instruction support for enhanced HPC and ML performance.
- AMD Infinity Guard technology to defend your data.[1]

IN THIS BRIEF

TEST METHODOLOGY

All test results presented in this Performance Brief are based on single 1P servers powered by a selection of AMD EPYC processors, as shown in Tables 1-3, below. AMD Engineering compared the relative performance of different processors and systems running Cadence Spectre X. Relative performance is the ratio of the average application runtime on the reference system (*ref*) to the average application run time on the system under test (*sut*), or *ref/sut*. For the purpose of this paper, reference application performance will always be normalized to 1.00, because if *ref*=*sut*, then *ref/sut*=1.00. Ratios greater than 1.00 (*sut*>*ref*) signify that the system under test performs higher than the reference system, with *ref*>*sut* indicating the test system under-performing the reference.

The tests described in this brief compared the relative performance of systems powered by different pairs of AMD EPYC processors. Each test used the system powered by the 3rd Gen AMD EPYC processor without AMD 3D V-Cache technology as the *ref* for that test (i.e., 73F3 for the 16-core tests, 75F3 for the 32-core tests, and 7763 for the top-of-stack tests). This highlights the impact of 3rd Gen AMD EPYC processors with AMD 3D V-Cache technology versus high-frequency 3rd Gen AMD EPYC processors. It also shows how selecting both high-frequency 4th Gen AMD EPYC processors and 4th Gen AMD EPYC processors with AMD 3D V-Cache technology further enhances performance.

These comparisons are relevant because EDA tools are generally core-performance sensitive. CPUs generally experience a trade-off between the number of cores and per-core performance mostly due to frequency. Customers seek a balance between overall compute cost and workload productivity. AMD investigated this trade-off between per-core performance and the total number of cores by selecting AMD EPYC parts with varying core counts to show our compelling offerings striking the best balance.

AMD used eight processor cores to run each copy of the full Cadence Spectre X application. This means that all processors tested ran a number of simultaneous jobs equal to total processor cores/8 simultaneous copies of the full application. For example, a system with a 32-core AMD EPYC 75F3 ran four simultaneous copies of the full application because 32 CPU cores/8 cores per copy = 4 copies. Affinity (CPU pinning) was used for Cadence Spectre X testing in accordance with the Cadence recommendation to pin CPUs on the same NUMA node when possible.

These results were then used to calculate the following metrics:

- **Runtime:** This test captured the elapsed runtime (in seconds) for each copy. These run times were then summed and divided by the number of running copies (e.g., 2 on a 16-core system) to obtain the average run time for that benchmark. The benchmark was run three times on each server. Finally, these averages were summed and divided by three to yield the average application performance on a fully loaded system.
- **Throughput:** This test measures the number of jobs completed per hour and is calculated as (1/average runtime)*number of concurrent jobs. For example, if a 32-core system is running four concurrent jobs with an average runtime of 2.5 hours, then the Throughput equals (1/2.5)*4 = 1.6 jobs per hour.
- **Performance-per-Watt:** This is the Throughput divided by the average socket power in Watts as measured by turbostat v21.05.04 (PkgWatt metric) at five-second intervals for the duration of each test. For example, if a test took exactly one hour to complete, then turbostat would return 720 results because an hour consists of 3600 seconds and 3600/5=720. This is appropriate because watts measure energy over time and throughput measures jobs over time. More specifically, the average of the measured turbostat values is calculated, thus providing a single Watt value for the benchmark. The Throughput is then divided by the single Watt value for the same benchmark to obtain the Performance-per-Watt value. The uplift is then calculated as (*sut_throughput*/*sut_watts*)/(*ref_throughput*/*ref_watts*).

Testing ran the Cadence Spectre X SPICE DDR PLL transient analysis of a 5nm DDR PLL with 1.8M nodes.

DETAILED TEST RESULTS (16 CORES)

This section presents the Runtime, Throughput, and Performance-per-Watt uplifts provided by the 3rd Gen AMD EPYC 7373X, 4th Gen AMD EPYC 9174F, and 4th Gen AMD EPYC 9184X processors versus the 3rd Gen AMD EPYC 73F3 processor. These results show that the 16-core AMD EPYC 9184X processor with AMD 3D V-Cache technology provides the highest overall uplift on all three metrics. All processors ran two simultaneous jobs using eight cores per job (see Test Methodology on Page 2).

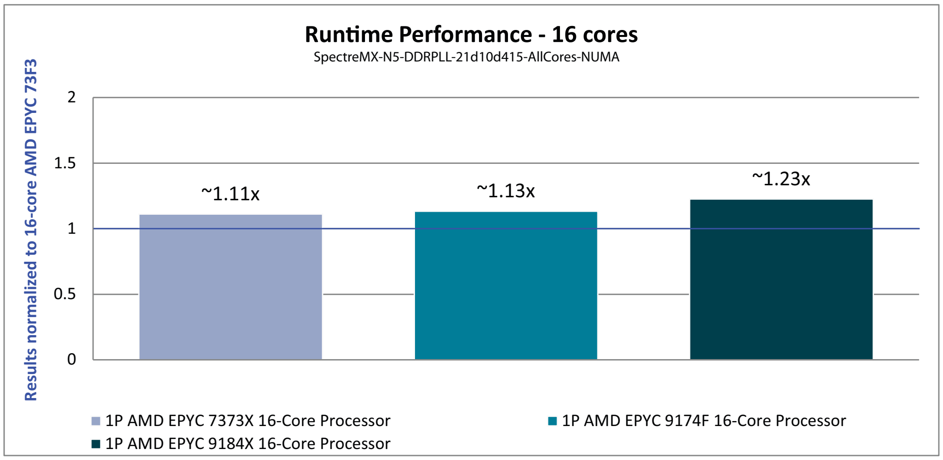


Figure 1: Runtime performance of select 16-core 3rd Gen and 4th Gen 16-core AMD EPYC processors normalized to the 16-core 3rd Gen AMD EPYC 73F3 running Cadence Spectre X Simulator

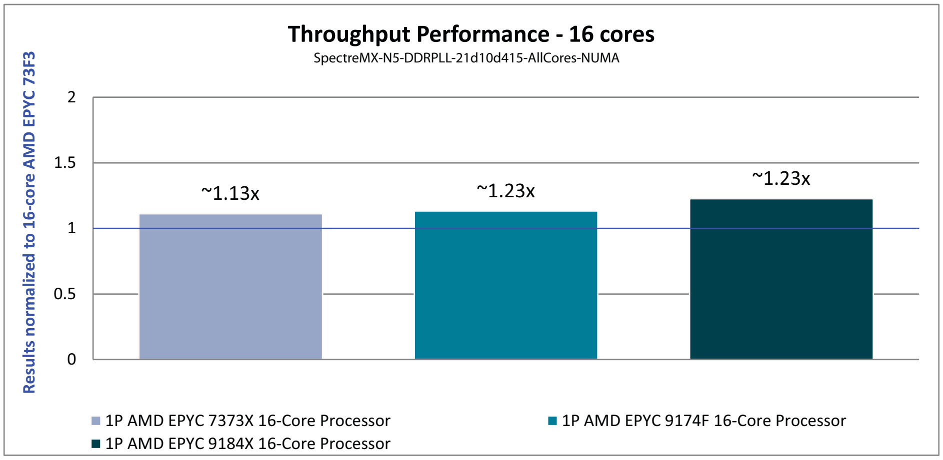


Figure 2: Throughput performance of select 16-core 3rd Gen and 4th Gen 16-core AMD EPYC processors normalized to the 16-core 3rd Gen AMD EPYC 73F3 running Cadence Spectre X Simulator7

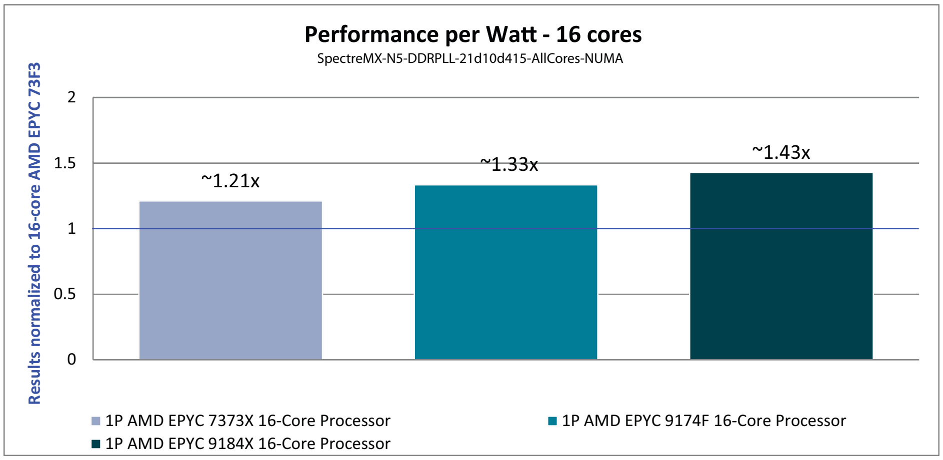


Figure 3: Performance-per-Watt of select 16-core 3rd Gen and 4th Gen 16-core AMD EPYC processors normalized to the 16-core 3rd Gen AMD EPYC 73F3 running Cadence Spectre X Simulator

DETAILED RESULTS (32 & 48 CORES)

This section presents the Runtime, Throughput, and Performance-per-Watt uplifts provided by the 3rd Gen AMD EPYC 7573X, 4th Gen AMD EPYC 9374F, and 4th Gen AMD EPYC 9384X processors versus the 3rd Gen AMD EPYC 75F3 processor. These results show that the 32-core AMD EPYC 9384X processor with AMD 3D V-Cache technology provides the highest overall uplift on all three metrics. All of the 32-core processors ran four simultaneous jobs using eight cores per job (see Test Methodology on Page 2).

These tests also included the high-frequency 48-core AMD EPYC 9474F processor as a mid-level option with denser cores. The 16 extra cores in this processor delivered higher throughput because this processor was running six simultaneous jobs instead of four; however, the 32-core AMD EPYC is the clear leader for runtime performance.

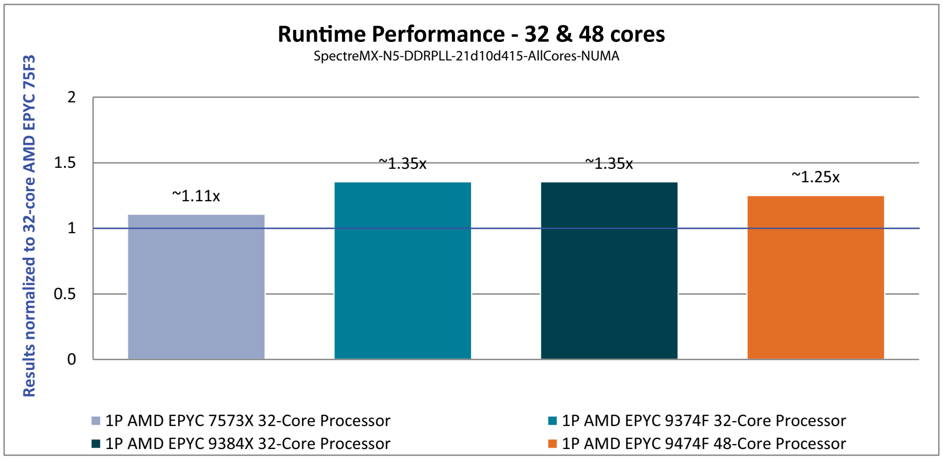


Figure 4: Runtime performance of select 32-core and 48-core 3rd Gen and 4th Gen AMD EPYC processors normalized to the 32-core 3rd Gen AMD EPYC 75F3 running Cadence Spectre X Simulator

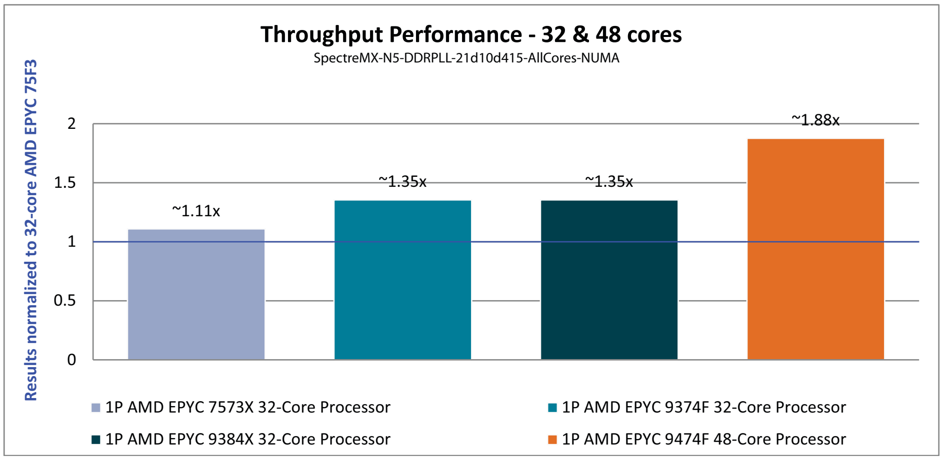


Figure 5: Throughput performance of select 32-core and 48-core 3rd Gen and 4th Gen AMD EPYC processors normalized to the 32-core 3rd Gen AMD EPYC 75F3 running Cadence Spectre X Simulator

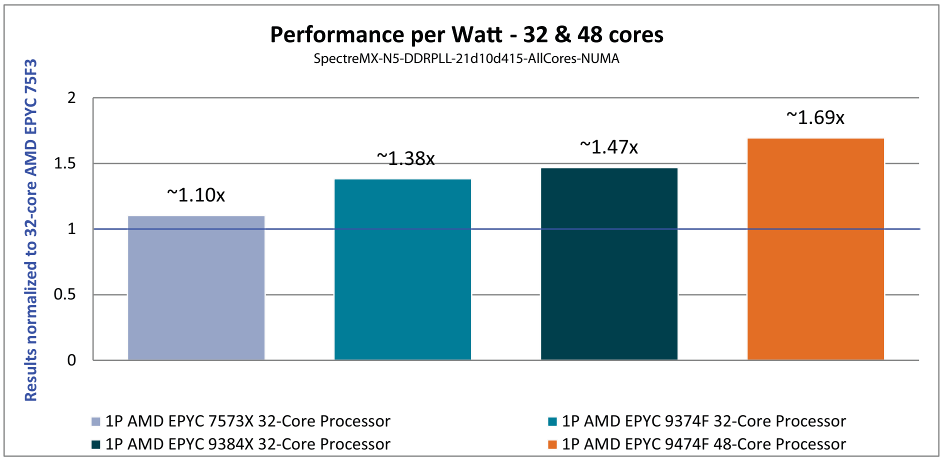


Figure 6: Performance-per-Watt of select 32-core and 48-core 3rd Gen and 4th Gen AMD EPYC processors normalized to the 32-core 3rd Gen AMD EPYC 75F3 running Cadence Spectre X Simulator

DETAILED RESULTS (TOP OF STACK)

This section presents the Runtime, Throughput, and Performance-per-Watt uplifts provided by the "top of stack" 3rd Gen ("Zen 3") and 4th Gen ("Zen 4") AMD EPYC processors, where "top of stack" means the processor in each family with the highest core count. Thus, these tests compared the 64-core 3rd Gen AMD EPYC 7773X, 96-core 4th Gen AMD EPYC 9654, and 4th Gen AMD EPYC 9684X processors versus the 64-core 3rd Gen AMD EPYC 7763 processor. (AMD EPYC 97x4 processors are intended for cloud-native workloads and were not included in these comparisons.) All of the 64-core processors ran eight simultaneous jobs, and all of the 96-core processors ran twelve simultaneous jobs using eight cores per job (see Test Methodology on Page 2). These results show that the 96-core AMD EPYC 9684X processor with AMD 3D V-Cache technology provides the highest overall uplift on all three metrics.

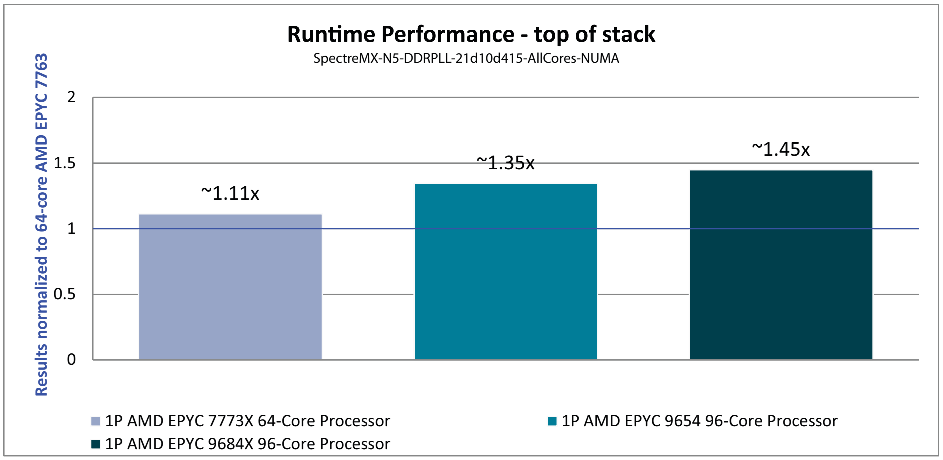


Figure 7: Runtime performance of select top-of-stack 3rd Gen and 4th Gen AMD EPYC processors normalized to the 64-core 3rd Gen AMD EPYC 7763 running Cadence Spectre X Simulator

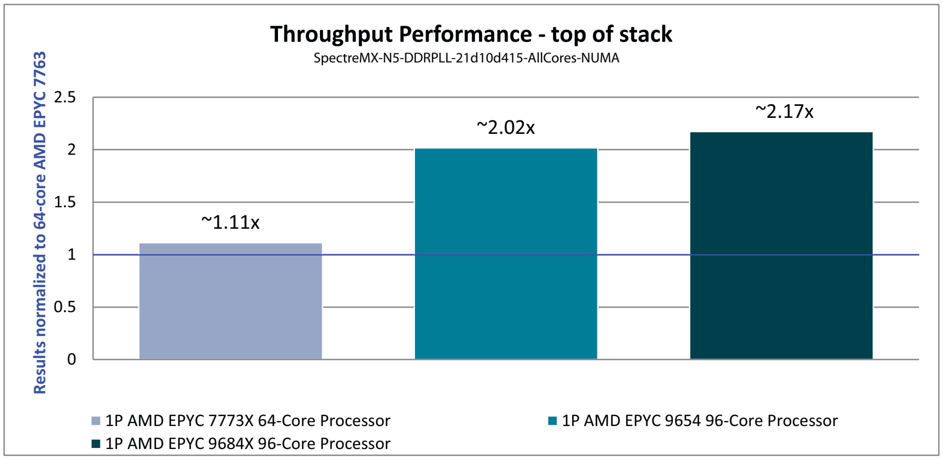


Figure 8: Throughput performance of select top-of-stack 3rd Gen and 4th Gen AMD EPYC processors normalized to the 64-core 3rd Gen AMD EPYC 7763 running Cadence Spectre X Simulator

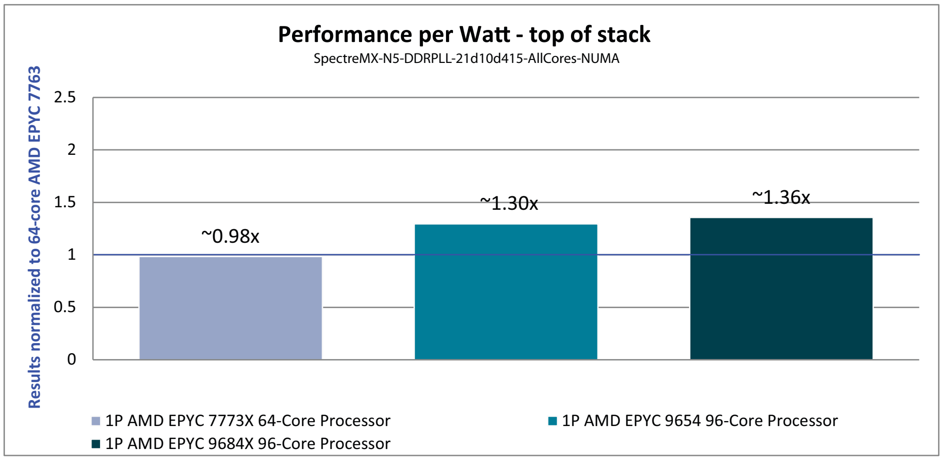


Figure 9: Performance-per-Watt of select top-of-stack 3rd Gen and 4th Gen AMD EPYC processors normalized to the 64-core 3rd Gen AMD EPYC 7763 running Cadence Spectre X Simulator

AMD EPYC 9004 SERIES PROCESSORS

AMD EPYC 9004 Series Processors continue to redefine the standards for modern datacenters.4th Gen AMD EPYC processors are built on the innovative x86 architecture and "Zen 4" core. 4th Gen AMD EPYC processors deliver efficient, optimized performance by combining high frequencies, the largest-available L3 cache, up to 128 (1P) or up to 160 (2P) lanes of PCIe® Gen 5 I/O, synchronized fabric and memory clock speeds, and support for up to 6 TB of DDR5-4800 memory. Built-in security features, such as AMD Infinity Fabric™ technology, Secure Memory Encryption (SME), and Secure Encrypted Virtualization (SEV-SNP) help protect data while it is in use.[1]

AMD 3D V-CACHE™ TECHNOLOGY

Some AMD EPYC 7003 and 9004 Series Processors include AMD 3D V-Cache™ die stacking technology that enables more efficient chiplet integration. AMD 3D chiplet architecture stacks L3 cache tiles vertically to provide up to 96MB of L3 cache per die (and up to either 768 MB or 1152 MB L3 Cache per socket for 3rd and 4th Gen AMD EPYC processors, respectively) while still providing socket compatibility with all same-generation AMD EPYC models. 3rd Gen AMD EPYC processors use Socket SP3 and 4th Gen AMD EPYC 9004 Series Processors use Socket SP5.

AMD EPYC processors with AMD 3D V-Cache technology employ industry-leading logic stacking based on copper-to-copper hybrid bonding "bumpless" chip-on-wafer process to enable over 200X the interconnect densities of current 2D technologies (and over 15X the interconnect densities of other 3D technologies using solder bumps),[2,3] which can translate to lower latency, higher bandwidth, and greater power and thermal efficiencies.

SYSTEM CONFIGURATION

Tables 1-3 provide the system configurations used for the testing described in this Performance Brief.

16-CORE SYSTEM CONFIGURATION				
CPUs	1 x AMD EPYC 73F3	1 x AMD EPYC 7373X	1 x AMD EPYC 9174F	1 x AMD EPYC 9184X
Frequency: Base | Boost[4]	2.95 GHz | 4.00 GHz	3.05 GHz | 3.80 GHz	4.10 GHz | 4.40 GHz	3.55 GHz | 4.20 GHz
Cores	16			
L3 Cache	256 MB	768 MB	256 MB	768 MB
Memory	8 x 64GB DDR4 3200 (512 GB total)	16 x 64GB DDR4 3200 (1 TB total)	12 x 64GB DDR5 4800 (768 GB total)	12 x 64GB DDR5 4800 (768 GB total)
NIC	Mellanox MT27710 Family [ConnectX-4 Lx] @ 50 Gbps		Broadcom NetXtreme BCM5720 Gigabit Ethernet PCIe @ 1 Gbps	
NVMe Storage	1 x 1.7 TB	1 x 1.2 TB	1 x 1.5 TB	
BIOS Version	RYM1009B		TTI1002D	TTI1003F
BIOS Settings	SMT=OFF, NPS=2			
OS	RHEL 8.6 (Ootpa), GCC v8.5.0 20210514 kernel 4.18.0-372.19.1.el8_6.x86_64			
OS Settings	throughput-performance			

Table 1: 16-core AMD EPYC system configuration

32- AND 48-CORE SYSTEM CONFIGURATION					
CPUs	1 x AMD EPYC 75F3	1 x AMD EPYC 7573X	1 x AMD EPYC 9374F	1 x AMD EPYC 9384X	1 x AMD EPYC 9474F
Frequency: Base | Boost[4]	2.95 GHz 4.00 GHz	2.80 GHz 3.60 GHz	3.85 GHz 4.30 GHz	3.10 GHz 3.90 GHz	3.60 GHz 4.10 GHz
Cores	32				48
L3 Cache	256 MB	768 MB	256 MB	768 MB	256 MB
Memory	8 x 64GB DDR4 3200 (512 GB total)	16 x 64GB DDR4 3200 (1 TB total)	12 x 64GB DDR5 4800 (768 GB total)		
NIC	Mellanox MT27710 Family [ConnectX-4 Lx] @ 50 Gbps		Broadcom NetXtreme BCM5720 Gigabit Ethernet PCIe @ 1 Gbps		
NVMe Storage	1 x 1.7 TB	1 x 1.2 TB	1 x 1.5 TB		
BIOS Version	RYM1009B		TTI1002D	TTI1003F	TTI1002D
BIOS Settings	SMT=OFF, NPS=2				
OS	RHEL 8.6 (Ootpa), GCC v8.5.0 20210514 kernel 4.18.0-372.19.1.el8_6.x86_64				
OS Settings	throughput-performance				

Table 2: 32- and 48-core AMD EPYC system configuration

TOP-OF-STACK SYSTEM CONFIGURATION				
CPUs	1 x AMD EPYC 7763	1 x AMD EPYC 7773X	1 x AMD EPYC 9654	1 x AMD EPYC 9684X
Frequency: Base | Boost[4]	2.45 GHz | 3.50 GHz	2.20 GHz | 3.50 GHz	2.40 GHz | 3.70 GHz	2.55 GHz | 3.70 GHz
Cores	64		96	
L3 Cache	256 MB	768 MB	384 MB	1152 MB
Memory	8 x 128GB DDR4 3200 (1 TB total)		12 x 64GB DDR5 4800 (768 GB total)	
NIC	Mellanox MT27710 Family [ConnectX-4 Lx] @ 50 Gbps		Broadcom NetXtreme BCM5720 Gigabit Ethernet PCIe @ 1 Gbps	
NVMe Storage	1 x 3.3 TB		1 x 1.5 TB	
BIOS Version	RYM1009B		TTI1002D	TTI1003F
BIOS Settings	SMT=OFF, NPS=2			
OS	RHEL 8.6 (Ootpa), GCC v8.5.0 20210514 kernel 4.18.0-372.19.1.el8_6.x86_64			
OS Settings	throughput-performance			

Table 3: Top-of-stack AMD EPYC system configuration

APPENDIX: ADDITIONAL PERFORMANCE AND EFFICIENCY INFORMATION

Table 4 on the next page tabulated Runtime, Throughput, and Performance-per-Watt performance results normalized to the 16-core 3rd Gen AMD EPYC 73F3 processor for a more comprehensive overview of the results presented above. You can also normalize these results to any listed processor by dividing any result in a given column by any other result in the same column to determine the relative performance of any two processors. For example, you can determine the Throughput of a 96-core AMD EPYC 9684X processor relative to the Throughput of a 48-core AMD EPYC 9474F processor by dividing 5.07 by 3.03. In this example, the AMD EPYC 9684X processor has a ~1.67x Throughput uplift compared to the AMD EPYC 9474F processor.

PROCESSOR	CORES	RUNTIME	THROUGHPUT	PERFORMANCE-PER-WATT
AMD EPYC 73F3	16	1.00x	1.00x	1.00x
AMD EPYC 75F3	32	~0.81x	~1.62x	~1.30x
AMD EPYC 7763	64	~0.58x	~2.33x	~1.99x
AMD EPYC 7373X	16	~1.11x	~1.11x	~1.21x
AMD EPYC 7573X	32	~0.90x	~1.79x	~1.44x
AMD EPYC 7773X	64	~0.65x	~2.60x	~1.95x
AMD EPYC 9174F	16	~1.13x	~1.13x	~1.33x
AMD EPYC 9374F	32	~1.09x	~2.19x	~1.80x
AMD EPYC 9474F	48	~1.01x	~3.03x	~2.21x
AMD EPYC 9654	96	~0.78x	~4.71x	~2.57x
AMD EPYC 9184X	16	~1.23x	~1.23x	~1.43x
AMD EPYC 9384X	32	~1.09x	~2.19x	~1.91x
AMD EPYC 9684X	96	~0.84x	~5.07x	~2.69x

Table 4: Runtime, Throughput, and Performance-per-Watt uplifts compared to the 16-core 3rd Gen AMD EPYC processor

APPENDIX: POWER CONSUMPTION BOX CHART

Figure 10, below, shows the power consumption distribution in watts for each of the AMD EPYC processors, including the median and outliers. Turbostat v21.05.04 ran on each server during all testing described in this Performance Brief. The turbostat output was saved to a file every five seconds. The box chart shown in Figure 10 (see next page) plots the values for the turbostat 'PkgWatt' metric, which is a measure of the socket power consumption in Watts. The wide boxes within Figure 10 show where approximately 50% of the power consumption results fall, and the other marks indicate power consumption results that lie outside this 50% range. The measurement is for socket power only and does not include motherboard, memory, or any peripherals. The measurements were taken using turbostat software (PkgWatt metric) at five second intervals for the duration of the run.

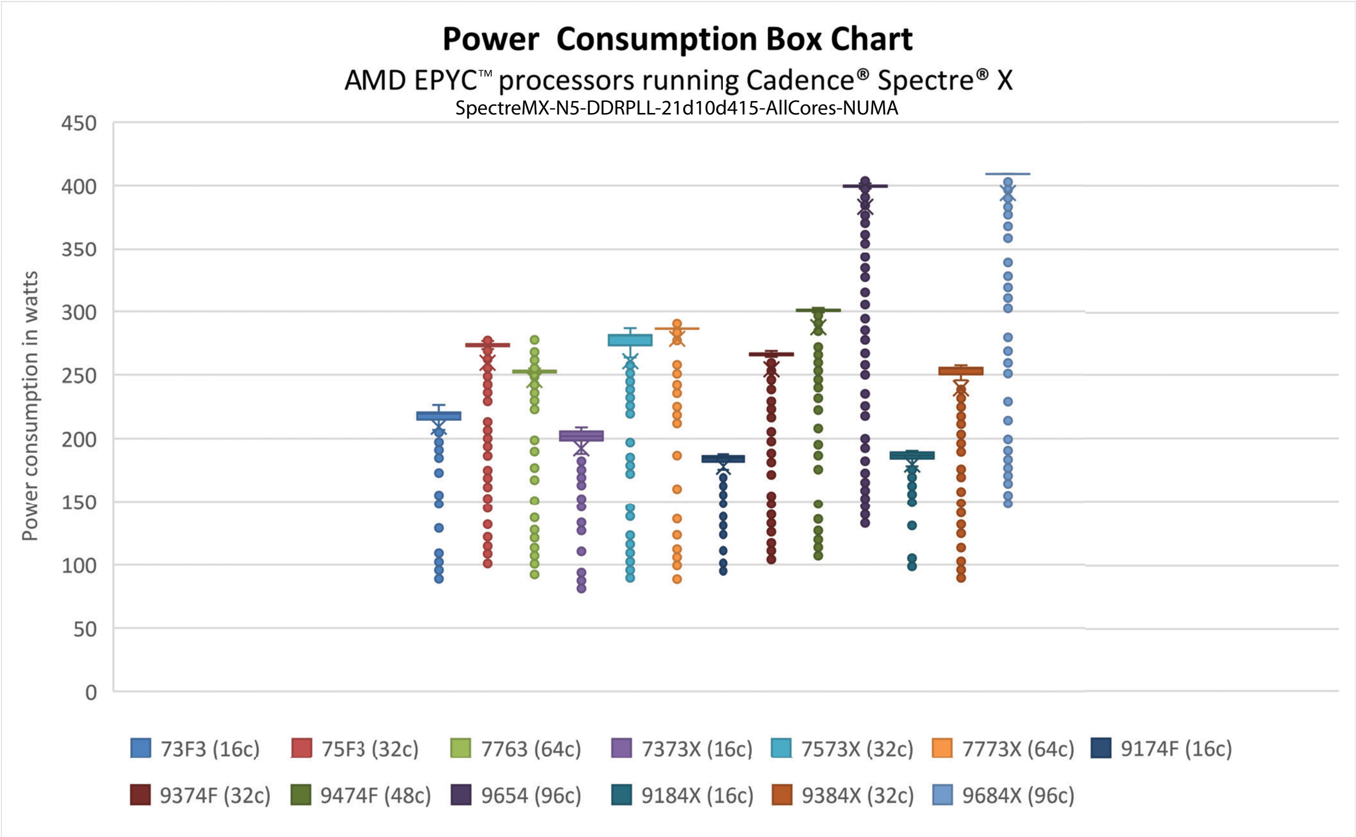


Figure 10: Power consumption box chart for all processors tested

FOR ADDITIONAL INFORMATION

Please see the following additional resources for more information about 4th Gen AMD EPYC features, architecture, and available models:

- AMD EPYC™ 9004 Series Processors
- AMD EPYC™ Tuning Guides
- AMD EPYC™ Products

REFERENCES

1. 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
2. Based on calculated areal density and based on bump pitch between AMD hybrid bond AMD 3D V-Cache stacked technology compared to AMD 2D chiplet technology and Intel 3D stacked micro-bump technology. EPYC-026
3. Based on AMD internal simulations and published Intel data on "Foveros" technology specifications. EPYC-027
4. Maximum boost 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

AUTHORS

Philip Steinke, Brian Malley, and Anthony Hernandez contributed to this Performance Brief.

RELATED LINKS

- Cadence Spectre X Simulator*
- Cadence Spectre X Simulator Datasheet*
- AMD EPYC™ Processors
- AMD Documentation Hub

**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.*

AMD EPYC 9004 FOR HPC

4th Gen AMD EPYC processors deliver blazing per-core performance thanks to fast CPU frequencies, low latency memory, and a unified cache structure. AMD EPYC processors provide high bandwidth between nodes with support for PCIe® Gen 5 network devices and accelerators that greatly benefit HPC applications.

"ZEN 4" CORE & SECURITY FEATURES

Support for up to:

- 96 physical cores, 192 threads
- up to 1,152 MB of L3 cache per CPU
- 32 MB of L3 cache per CCD
- 6 TB of DDR5-4800 memory
- 128 1P, up to 160 2P PCIe® Gen 5 lanes

Infinity Guard security features[1]

- Secure Boot
- Encrypted memory with SME

CADENCE®

Cadence® is a leader in electronic design with more than 30 years of computational software expertise. The company applies its underlying Intelligent System Design strategy to deliver software, hardware, and IP that turn design concepts into reality.

CADENCE® SPECTRE® X SIMULATOR

Cadence® Spectre® X Simulator allows massively distributed simulation workloads to help boost speed and capacity. It performs advanced SPICE-accurate simulation with fast convergence, scalable performance, and a new mode for handling very large system simulations