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The Benefits of CXL® Memory PCIe Add-in Cards:

Expanding Memory Capacity and Performance

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Introduction

As data-intensive workloads continue to grow in complexity and scale, the demand for high-capacity, high-performance memory solutions has never been greater. Compute Express Link (CXL) technology has emerged as a game-changing solution, enabling affordable memory expansion, flexible scaling, improved performance, as well as allowing the disaggregation of memory resources from processors. This white paper explores the benefits of CXL memory PCIe Add-in Cards (AICs) from SMART Modular Technologies, focusing on single-width cards with four Registered DIMMs (RDIMMs) and dual-width cards with eight RDIMMs.

CXL Technology Overview

CXL is an open industry-standard interconnect protocol built on the PCIe physical layer. It provides low-latency, high-bandwidth connectivity between host processors and devices such as accelerators, memory buffers, and smart I/O devices. CXL maintains memory coherency between the CPU memory space and memory on attached devices, enabling resource sharing for higher performance and reduced software stack complexity.

SMART Modular Technologies' CXL Memory PCIe Add-in Cards

SMART Modular Technologies offers CXL memory AICs that leverage the CXL mem protocol to expand system memory capacity beyond what is available with directly attached RDIMMs to the CPU. These cards come in two primary configurations:

1. Single-width cards with four RDIMMs

2. Dual-width cards with eight RDIMMs
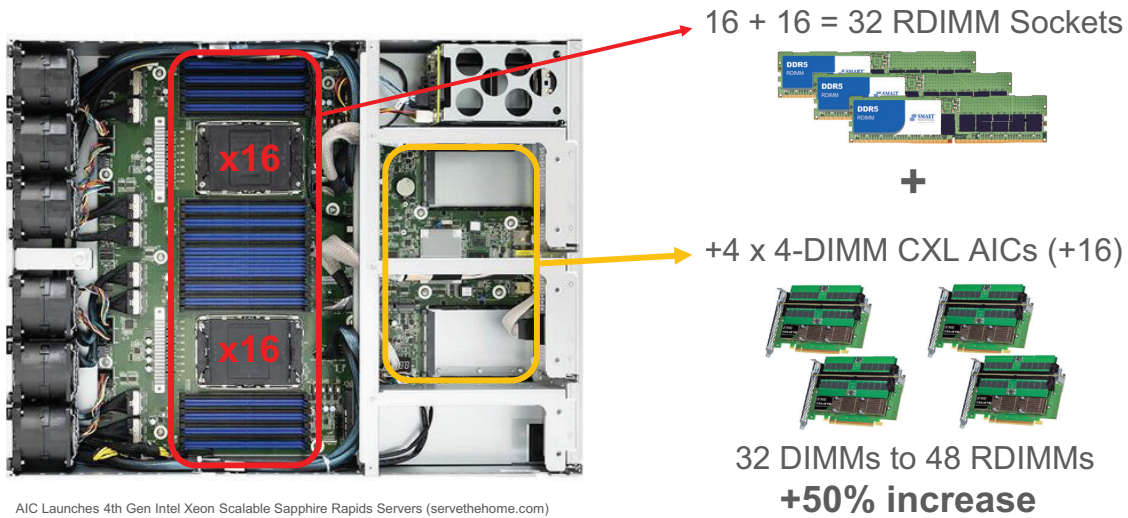
Benefits of CXL Memory AICs

1. Increased Memory Capacity

CXL memory AICs allow systems to significantly expand their memory capacity without the need for additional CPU sockets or proprietary memory interfaces. For example:
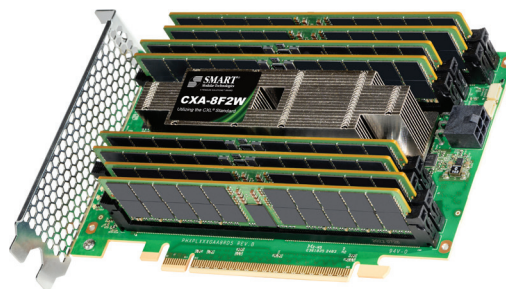
• A single-width FHHL card with four 128GB RDIMMs can add up to 512GB of memory
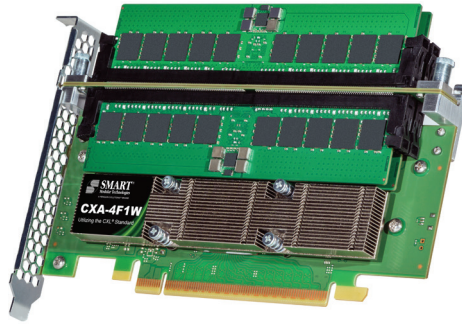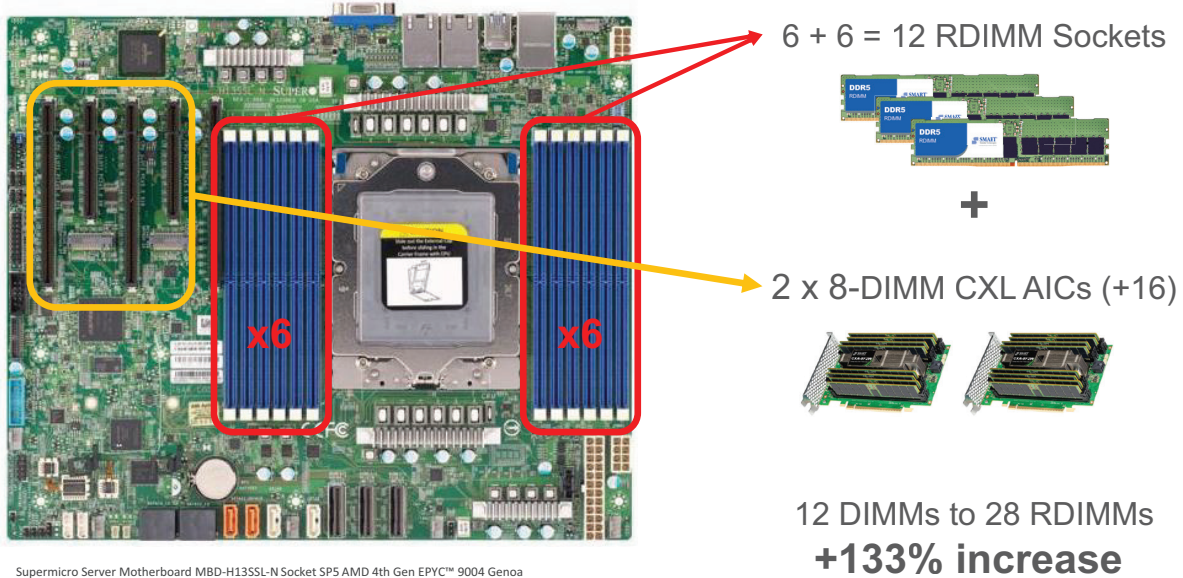

An example is shown below how to obtain 50% memory capacity increase in a dual-socket CPU system using four 4-DIMM AICs

AIC Launches 4th Gen Intel Xeon Scalable Sapphire Rapids Servers (servethehome.com)

16 + 16 = 32 RDIMM Sockets

+

+4 x 4-DIMM CXL AICs (+16)

32 DIMMs to 48 RDIMMs
+50% increase

• A dual-width FHHL card with eight 128GB RDIMMs can add up to 1TB of memory

An example is shown below how to obtain 133% memory capacity increase in a single-socket CPU system using two 8-DIMM AICs


Supermicro Server Motherboard MBD-H13SSL-N Socket SP5 AMD 4th Gen EPYC™ 9004 Genoa

6 + 6 = 12 RDIMM Sockets

+

2 x 8-DIMM CXL AICs (+16)

12 DIMMs to 28 RDIMMs
+133% increase

This expanded capacity is essential for memory-intensive applications such as in-memory databases, AI/ML workloads, and large-scale data analytics.
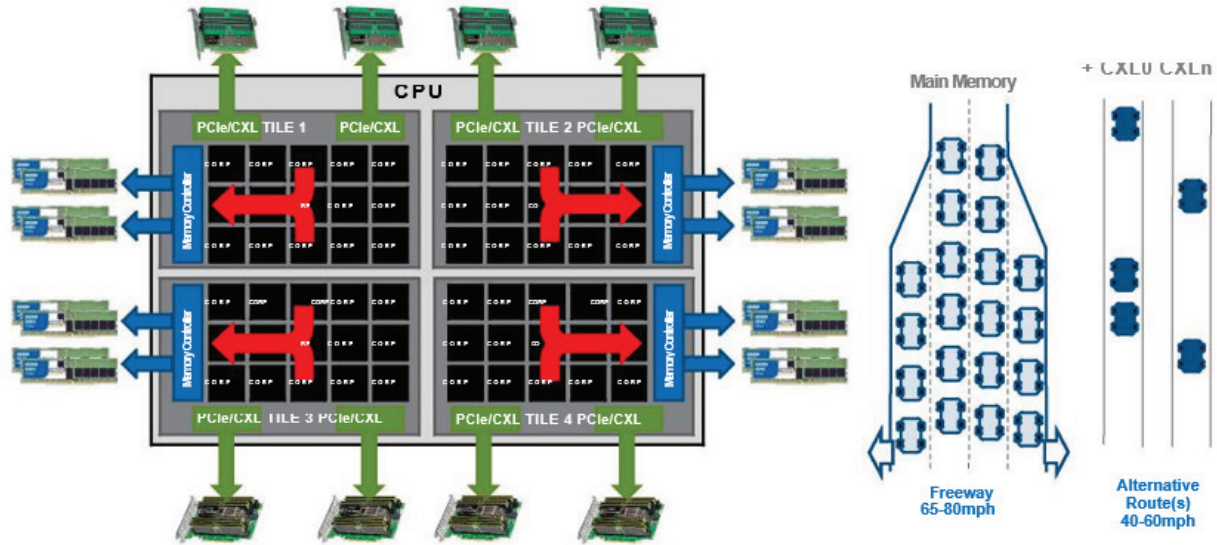
2. Flexible Memory Scaling

CXL AICs provide a modular approach to memory expansion, allowing organizations to scale their memory resources as needed. This flexibility is particularly valuable in cloud and enterprise environments where workload demands can fluctuate rapidly.

3. Improved Performance

By leveraging the CXL protocol, these AICs offer lower latency compared to traditional PCIe-based storage expansion. CXL memory can be accessed with with latencies near 200ns, significantly faster than NVMe SSDs and only slightly slower than direct-attached RDIMMs. The diagram below illustrates where CXL-attached memory fits in the memory hierarchy.

CXL Enables a New Tier of Memory

Performance/Latency Spectrum
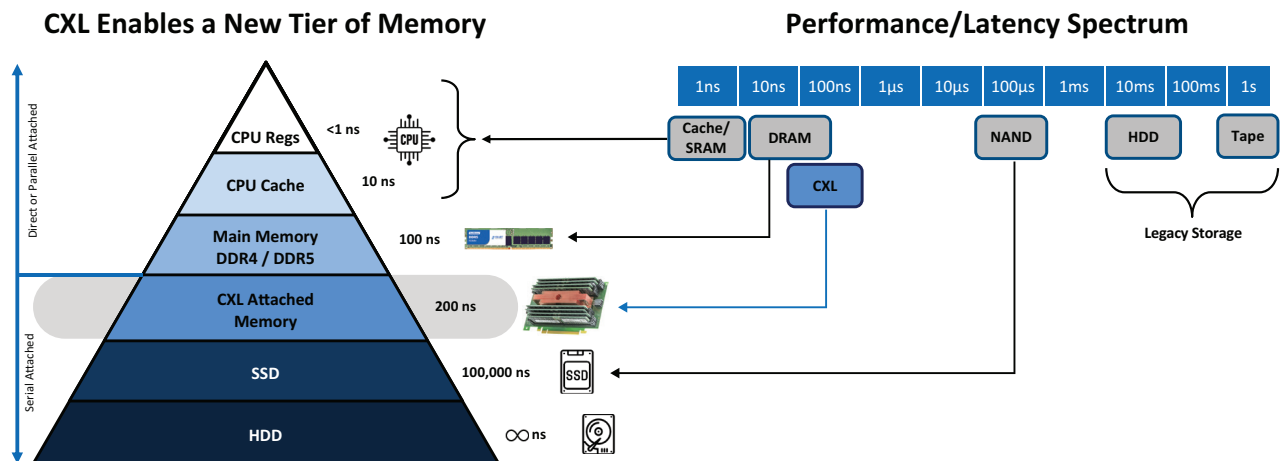
Higher overall memory bandwidth is also achieved using CXL AICs. A single-width card with four RDIMMs typically uses one x16 CXL controller, capable of a total bandwidth of 64GB/s. This bandwidth combined with the additional CXL memory channels beyond what's available natively on the CPU, significantly increases the overall memory bandwidth. This reduces contention and queueing for memory access.

Reference: A Case for CXL-Centric Server Processors

4. Flexible Cost-Effective Memory Expansion

SMART's CXL AICs provide a modular approach to memory expansion, allowing organizations to scale resources as needed. This flexibility is particularly valuable in cloud and enterprise environments with fluctuating workload demands. The cards offer a more economical approach to expanding system memory compared to upgrading CPUs or entire server platforms. For instance, using a combination of lower-capacity CPU-attached DIMMs and a CXL AIC can provide equivalent memory capacity at a lower cost than using all high-capacity DIMMs. The illustration below describes a 40% cost reduction case study for a 1TB memory system.
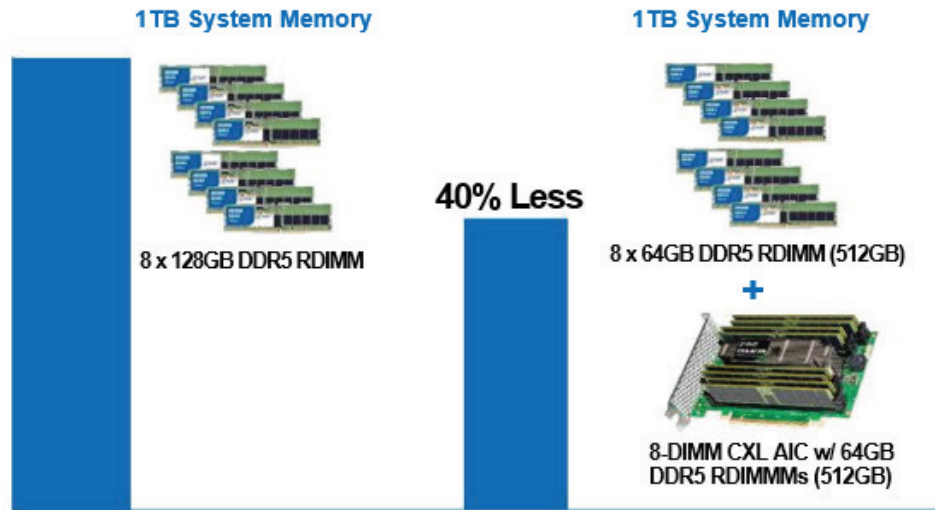
The system is configured using mainstream 64GB DDR5 RDIMMs and one AIC instead of using all 128GB DDR5 RDIMMs and no AIC. This savings excludes the even larger savings of not have to use two CPUs.

Capacity / Price/Gb

Capacity	Price/Gb
32GB	1.0x
64GB	1.0x
96GB	1.1x
128GB	2.0x
256GB	3.0x

DDR5 DIMM Price

1TB System Memory — 8 x 128GB DDR5 RDIMM

40% Less

1TB System Memory — 8 x 64GB DDR5 RDIMM (512GB) + 8-DIMM CXL AIC w/ 64GB DDR5 RDIMMMs (512GB)

5. Seamless Integration with Existing Infrastructure

SMART's CXL AICs are designed to work with standard PCIe slots as long as they support the CXL standard, making them compatible with a wide range of existing server platforms. This backward compatibility allows organizations to leverage CXL technology without a complete infrastructure overhaul.

These benefits make CXL AICs an attractive option for expanding memory capacity and performance in data center and enterprise environments, particularly for memory-intensive applications like AI/ML workloads, large In-Memory databases, and data analytics.

Real World Results

In a study conducted by Micron and AMD on CXL memory expansion using actual hardware platforms, highlighted. The article highlighted how CXL memory expansion can address challenges in data-intensive workloads, including AI, high-performance computing, and In-Memory databases. The table below provides three real-world performance data and analysis scenarios.

In-Memory Database (MS SQL + TPC-H)	Machine Learning (Apache Spark™ SVM)	High Performance Computing (CloverLeaf)
• Consumes only 50% of memory bandwidth • Capacity limited	• Memory bound workload • Sensitive to latency & capacity	• Bandwidth intensive workload • 80% mapped to DRAM • 20% mapped t CXL
• 44% - 88% reduction in SSD paging I/Os • 23% performance Improvement	• 2.21x performance improvement compared to DRAM only	• CXL increases memory bandwidth by 33% • 17% performance improvement

Sources: CXL Memory Expansion: A Closer Look on Actual Platform by Micron and AMD

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Summary

SMART Modular Technologies' CXL memory Add-in Cards offer a powerful solution for addressing the growing memory demands of modern data centers and high-performance computing environments. By providing flexible, cost-effective memory expansion with low latency and high bandwidth, these AICs enable organizations to optimize their infrastructure for data-intensive workloads while leveraging existing investments in server hardware.

As CXL technology continues to evolve, SMART Modular Technologies remains at the forefront, driving innovations in memory expansion and disaggregation. This commitment paves the way for more efficient, scalable, and performant data center architectures, transforming the landscape of enterprise computing.

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