

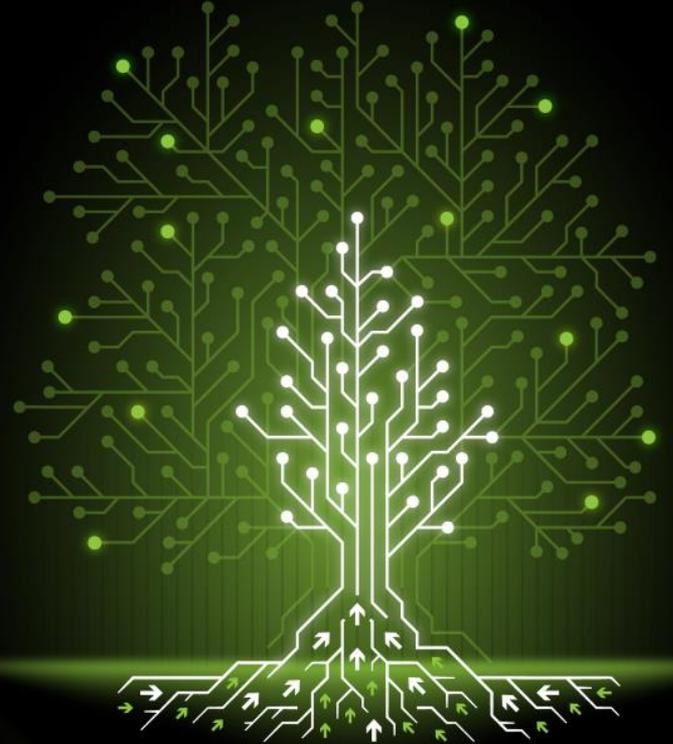
Memory Solutions with CXL

Scaling Innovation Through Collaboration



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Memory Solutions with CXL

Arthur Sainio, Director of Product Marketing, SMART Modular Technologies



OPEN

Compute Project

SOLUTION PROVIDER[®]



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SMART Global Holdings (SGH) at-a-Glance



Powering growth Expanding possibilities

At SGH, we design and develop enterprise solutions that support and advance our world. Across our computing, memory, and LED lines of businesses we are focused on serving our customers by providing deep technical knowledge and expertise, custom design engineering, build to order flexibility, and a commitment to best-in-class quality.

SGH
NASDAQ

1988
Year Founded

~3,700
Employee count

\$1.8B
FY 2022 Revenue

2,154
Patents & Applications

\$3.62
FY 2022 Non-GAAP EPS



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SHG Companies



Memory Solutions



PENGUIN
SOLUTIONS



Intelligent Platform
Solutions (IPS)



CREE LED

LED Solutions



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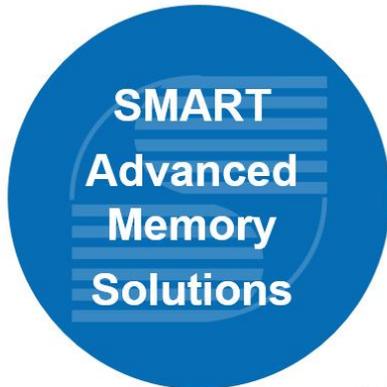
CXL[®] Convergence



Kestral 2TB of Optane Memory expansion for Intel and non-Intel CPU based datacenters



Tahoe E1.S for cache coherent, low-latency memory expansion over a serial interface



Gen-Z E3.S for composable memory expansion in data centers. Gen-Z folding into CXL



Custom-designed backup power solutions for persistent memory application



NVDIMM persistent memory for storage system acceleration



ZMM for cache coherent memory expansion and acceleration



Differential DIMM for coherent serial-connected high bandwidth memory



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CXL[®] Convergence



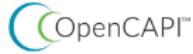
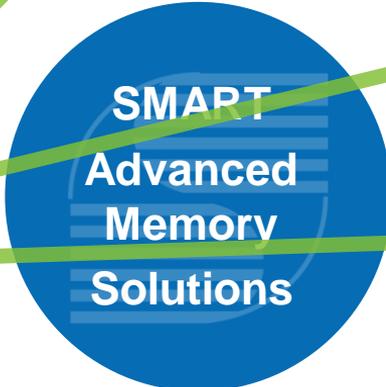
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CXL[®] Applications and Use Cases



AI

AI & Machine Learning

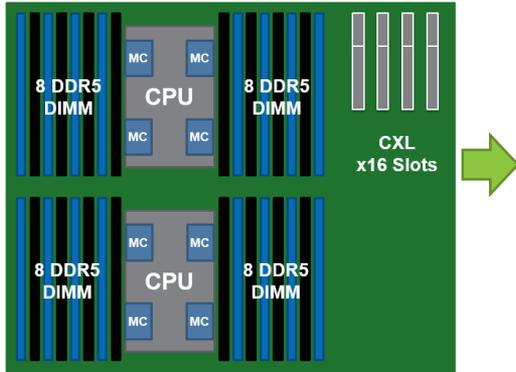
- Natural language processing
- Image recognition
- Autonomous vehicles



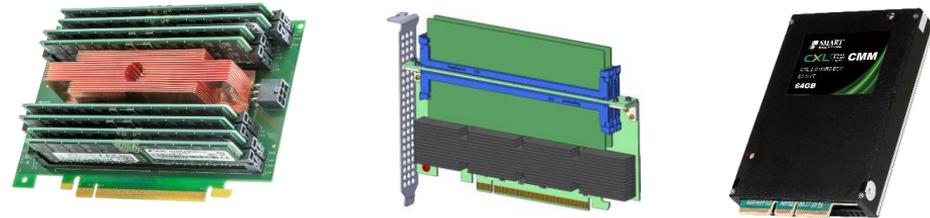
SERVER

Large Scale IMDBs

- Video editing
- Fintech
- Real time analytics

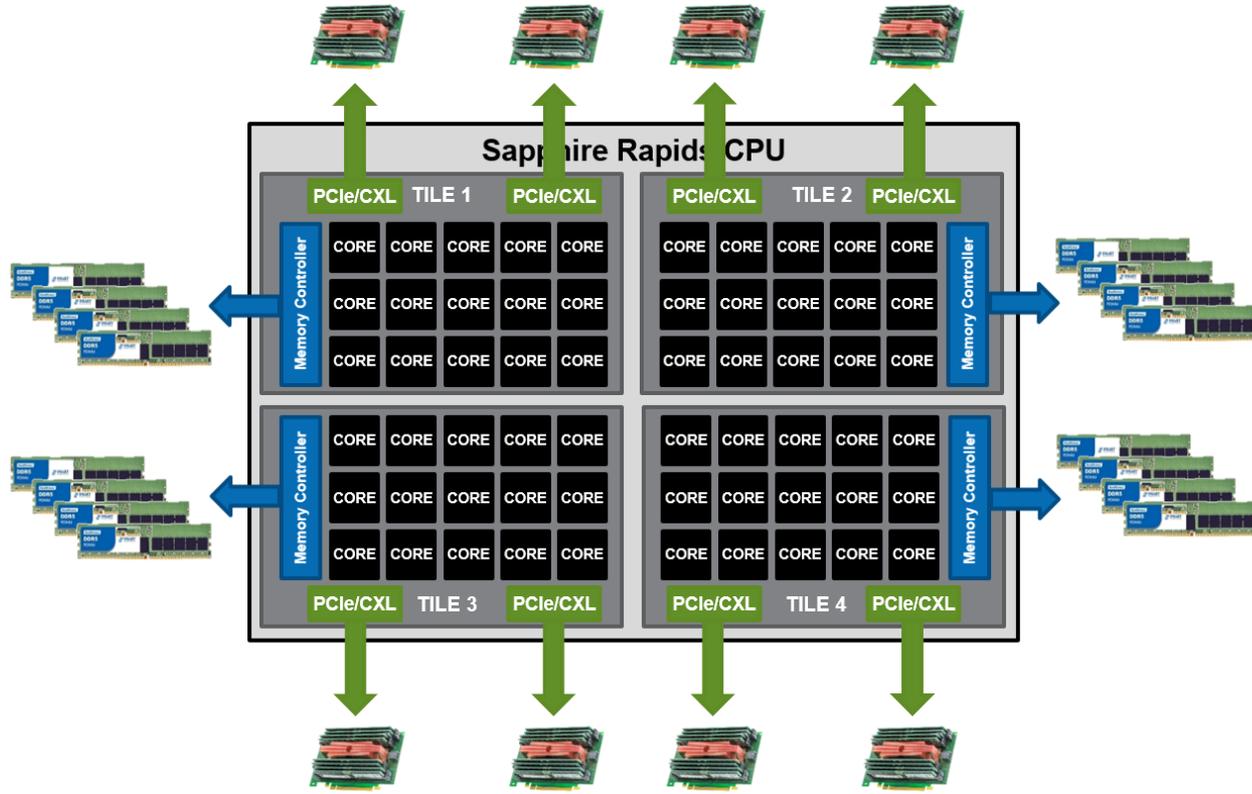


DDR5 Server Motherboard

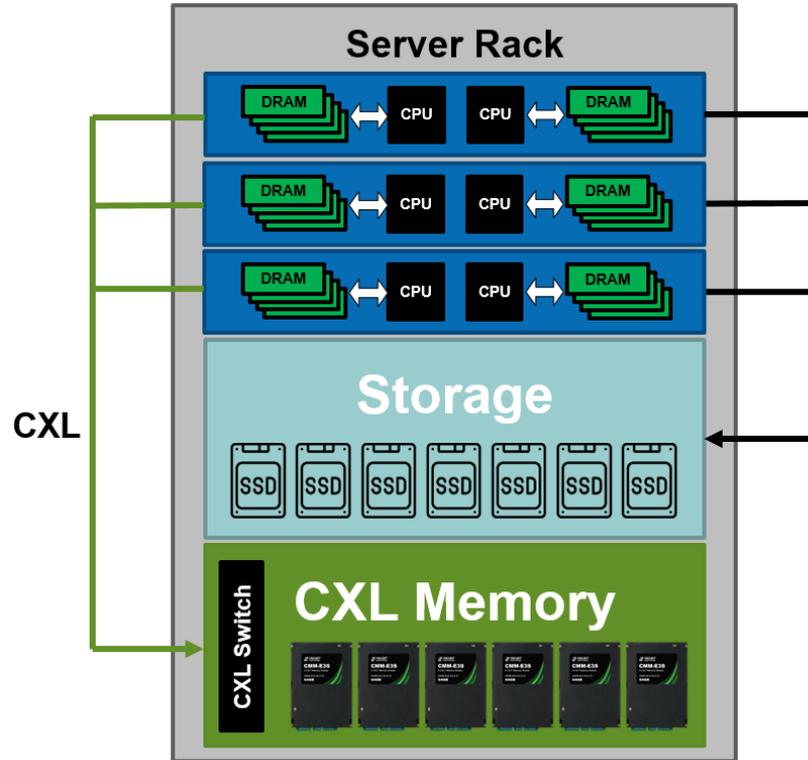


Memory Expansion with CXL

Memory Controller Queuing



Memory Disaggregation



CXL® Feature Adoption



CXL Adoption Timeline

Features	2023	2024	2026
	CXL 1.0 / 1.1	CXL 2.0	CXL 3.0
Release date	2019	2020	1H 2022
Max link rate	32GTs	32GTs	64GTs
Flit 68 byte (up to 32 GTs)	✓	✓	✓
Flit 256 byte (up to 64 GTs)			✓
Type 1, Type 2 and Type 3 Devices	✓	✓	✓
Memory Pooling w/ MLDs		✓	✓
Global Persistent Flush		✓	✓
CXL IDE		✓	✓
Switching (Single-level)		✓	✓
Switching (Multi-level)			✓
Direct memory access for peer-to-peer			✓
Symmetric coherency (256 byte flit)			✓
Memory sharing (256 byte flit)			✓
Multiple Type 1/Type 2 devices per root port			✓
Fabrics (256 byte flit)			✓

Not supported
 ✓ Supported

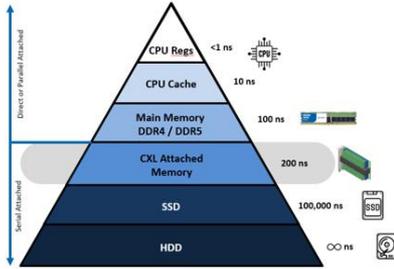


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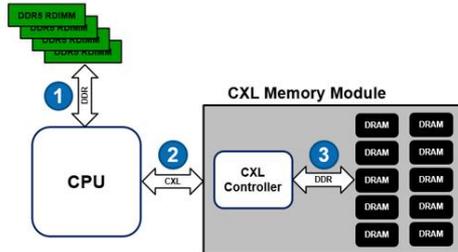
Preliminary Performance Results



Latency	Theoretical	Measured
DDR5-4800	100 ns	100.5 ns
CXL x8	200 ns	212.6 ns*



Bandwidth	Theoretical	Measured
DDR5-4800	38.4 GB/s	29.9 GB/s
CXL x16	63.0 GB/s	36.0 GB/s*



* Limited by initial CXL Controller DRAM speed
Using Intel MLC



Memory Expansion with AICs



- Can support up to 4TB
- Cost reduction 1TB server
 - Using 8 64GB DDR5 RDIMMs + AIC with 8 64GB DDR5 RDIMMs
 - No need for 128GB RDIMMs
 - Use only 1 CPU
- Can support DDR4 RDIMM re-use case with DDR4 AICs



SMART CXL[®] Expertise



Industry Standards Expertise

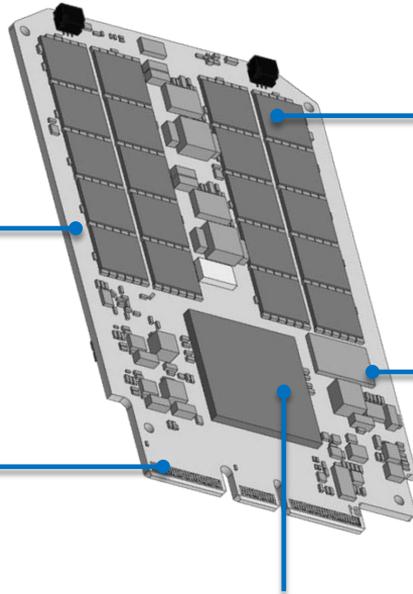


Validation & Test Expertise

- Memory and CPU qualification
- Memory Validation
- Test program development

Serial Standards and Solutions Expertise

- PCI Express
- NVMe
- Growing CXL Portfolio
 - E3.S
 - AICs
 - E1.S
 - NV-XMM



CXL Controller Partnerships

Memory Expertise

- Extensive DRAM & NAND Product Lines
- Diverse Form Factors
- Exceptional Industry Partnerships
 - Memory Suppliers
 - RCD Vendors
 - CPUs Vendors

Complex Memory + ASIC/FPGA Controllers Card Expertise

- Hardware Design
- FW & Software
- Test and Reliability
- High Volume Manufacturing
- High Quality trusted supplier to Tier 1 OEMs



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Thank you!

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