Oracle Database 23ai on Lenovo ThinkAgile VX and FX V4 Systems with VMware Cloud Foundation

Solution Brief

As enterprise data workloads grow in complexity and volume, IT teams require infrastructure that can deliver consistent Oracle database performance without sacrificing operational simplicity.

Lenovo ThinkAgile VX and FX V4 hyperconverged systems, powered by Intel Xeon 6 (Granite Rapids) processors and VMware Cloud Foundation (VCF), address these demands by combining validated hardware, software-defined storage via vSAN ESA, and unified lifecycle management into a single, scalable platform. VCF eliminates the complexity of traditional three-tier architectures, enabling Oracle database deployments that scale linearly by adding nodes without disrupting running workloads.

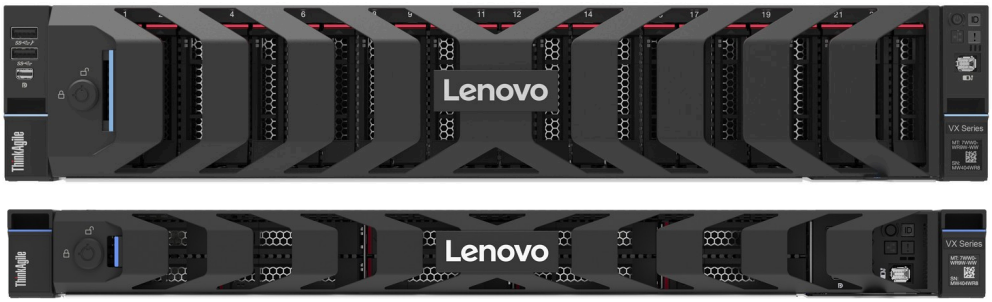

Figure 1. ThinkAgile VX650 V4 (top) and VX630 V4 (bottom) designed for VMware hyperconverged infrastructure

In our test environment, the validated solution described in this brief delivers the results listed in the following table.

Table 1. Summary of results

Metric	Value	Detail
Peak TPM	36.8M	Sustained across eight Oracle Database 23ai VMs on a four-node ThinkAgile VX650 V4 cluster (HammerDB OLTP).
TPM per VM	~4.6M	Average per-VM throughput, with each VM' pinned to a single NUMA socket for local CPU and memory.
Cores per node	96	Intel Xeon 6 (Granite Rapids) cores per dual-socket VX650 V4 node, with PCIe 5.0 and DDR5 memory.
NVMe storage	100%	All-NVMe vSAN Express Storage Architecture (ESA) delivers consistent low laency without external SAN complexity.

Business Challenge

Oracle Database underpins the most demanding transactional and analytical applications in the enterprise, yet the infrastructure beneath it is often the limiting factor. Traditional three-tier architectures that separate

compute, SAN storage, and networking add operational complexity, lengthen provisioning cycles, and multiply the number of vendors involved when problems arise. At the same time, Oracle performance and licensing efficiency are highly sensitive to how well the platform aligns CPU, memory, and storage.

IT teams deploying Oracle at scale consistently encounter the following obstacles:

- **Operational complexity:** Separate compute, storage, and network tiers slow provisioning, complicate patching, and increase the risk of misconfiguration across Day 0 to Day 2 operations.
- **Memory locality:** Oracle throughput degrades when virtual machines span NUMA boundaries, forcing remote memory access that adds latency and wastes licensed cores.
- **Storage predictability:** SAN contention and inconsistent I/O latency undermine the predictable response times that OLTP workloads require.
- **Multi-vendor support:** Fragmented support models across hardware, hypervisor, and storage vendors slow root-cause analysis and issue resolution.
- **Disruptive scaling:** Growing an Oracle estate on legacy infrastructure often requires forklift upgrades or re-architecture rather than incremental expansion.

Solution

Lenovo ThinkAgile VX and FX V4 with VMware Cloud Foundation (VCF) collapse the traditional three-tier stack into a single, factory-integrated hyperconverged platform. VCF environments are delivered as one validated system, and Lenovo acts as a single point of contact for purchasing, deployment, and support. Oracle Database 23ai runs in NUMA-aligned virtual machines on all-NVMe vSAN ESA storage, delivering the performance of dedicated hardware with the flexibility and lifecycle automation of a software-defined data center.

Figure 2. ThinkAgile FX650 V4 (top) and FX630 V4 (bottom) designed for flexible hyperconverged infrastructure

The following table shows how the solution addresses each of the business challenges.

Table 2. How business challenges are addressed

Business Challenge	**How the solution addresses it**
Operational complexity	VMware Cloud Foundation collapses the three-tier stack into one factory-integrated hyperconverged platform, and SDDC Manager automates Day 0 to Day 2 lifecycle management.
Memory locality	NUMA-aligned VM sizing with vSphere DRS host-affinity rules pins each Oracle VM to a single socket, keeping all CPU and memory access local.
Storage predictability	All-NVMe vSAN Express Storage Architecture (ESA) delivers consistent low latency without external SAN contention.
Multi-vendor support	Lenovo is the single point of contact for hardware, VMware software, and services through ThinkAgile Premier Support.

Business Challenge	How the solution addresses it
Disruptive scaling	Linear scale-out: add ThinkAgile VX and FX nodes for proportional Oracle throughput with no re-architecture or downtime.

Key aspects of the solution include the following:

- **Lenovo ThinkAgile VX650 V4 and FX650 V4**

  The ThinkAgile VX650 V4 is a 2-socket, 2U hyperconverged system featuring Intel Xeon 6 Scalable processors (Granite Rapids) with up to 96 cores per node, up to 8TB of DDR5 memory, PCIe 5.0, and up to 24 NVMe drives validated for vSAN ESA. The FX650 V4 is a purpose-built HCI appliance offering multi-hypervisor flexibility across VMware, Nutanix, and Microsoft stacks on a single hardware model, giving organizations investment protection and the freedom to transition between HCI software vendors.

- **VMware Cloud Foundation**

  VCF consolidates vSphere, vSAN ESA, NSX, and VCF Operations into a unified stack with an improved SDDC Manager for automated lifecycle management. vSAN ESA is the default storage architecture, delivering higher performance and space efficiency than the previous OSA model, while centralized management simplifies Oracle VM deployment, monitoring, and patching across on-premises and hybrid cloud environments.

- **Oracle Database 23ai**

  Oracle Database 23ai is Oracle's latest long-term support release, adding AI Vector Search for in-database RAG, True Cache for in-memory acceleration, JSON Relational Duality, Database In-Memory, and Multitenant consolidation. It deploys as a single instance or with Real Application Clusters (RAC) for high availability, and is fully compatible with Oracle Data Guard and Recovery Manager (RMAN) on VCF-managed infrastructure.

- **NUMA-Optimized, All-NVMe Design**

  Each Oracle VM is sized to a single NUMA socket and pinned with vSphere DRS host-affinity rules, keeping all vCPU scheduling and memory allocation local to one node and eliminating remote-memory latency. Datafiles, redo logs, and binaries are placed on separate virtual disks and controllers for parallel I/O, and BIOS is set to Maximum Performance. Together with all-NVMe vSAN ESA, this keeps CPU, rather than storage, as the primary performance determinant under OLTP load.

Use Cases

The combination of Oracle Database 23ai, Intel Xeon 6 processors, and VMware Cloud Foundation on ThinkAgile VX and FX V4 supports a broad range of database scenarios on a single platform. The following use cases represent where organizations most commonly deploy this solution, from consolidating mission-critical transactional systems to enabling real-time analytics and AI-driven applications.

- **Mission-Critical OLTP Consolidation**

  Consolidate high-volume transactional systems such as ERP, e-commerce, and core banking onto a single hyperconverged platform, using NUMA-pinned VMs and all-NVMe storage to sustain low, predictable latency at scale.

- **Real-Time Analytics with Database In-Memory**

  Run analytical queries directly against live transactional data. Oracle Database In-Memory processes billions of rows per second on each core, enabling real-time business decisions without a separate analytics platform.

- **AI-Enabled Applications with AI Vector Search**

  Build Retrieval-Augmented Generation and semantic-search applications with Oracle AI Vector Search, storing and querying vectors alongside relational data in a single database and removing the need for a standalone vector store.

- **Large-Scale Consolidation with Multitenant**

  Use Oracle Multitenant to consolidate many pluggable databases into a single container database, simplifying lifecycle management while VCF adds capacity node by node as the estate grows.

- **Disaster Recovery and High Availability**

  Combine VMware Site Recovery Manager and vSAN stretched clusters with Oracle Data Guard and RMAN to deliver enterprise-grade disaster recovery and business continuity across sites.

Workloads

ThinkAgile VX and FX V4 with VCF support the full range of Oracle Database 23ai workloads on one platform. The validated reference configuration is a four-node ThinkAgile VX650 V4 cluster running eight Oracle database VMs (two per node, one per NUMA socket), each configured with 48 vCPUs and 512GB of memory on Oracle Linux 9.7.

The table below maps common workloads to the platform capabilities that support them.

Table 3. Workloads

Workload	Why it fits ThinkAgile VX and FX V4
Mission-critical OLTP	ERP, e-commerce, and core-banking transaction systems benefit from all-NVMe vSAN ESA low latency and NUMA-pinned VMs that keep Oracle SGA access local.
Mixed OLTP and analytics (HTAP)	Oracle Database In-Memory processes billions of rows per second per core, enabling real-time analytics against live transactional data on the same platform.
AI-enabled applications	Oracle AI Vector Search stores and queries vectors alongside relational data in-database, supporting RAG and semantic search without a separate vector store.
Database consolidation	Oracle Multitenant consolidates many pluggable databases into a container database, and VCF linear scaling adds capacity node by node.
Dev/test and DR	Rapid VM provisioning plus VMware Site Recovery Manager, vSAN stretched clusters, Oracle Data Guard, and RMAN deliver enterprise-grade availability.

In HammerDB OLTP testing derived from the TPC-C standard, this configuration sustained an aggregate 36.8 million TPM, averaging approximately 4.6 million TPM per VM. Because each VM was confined to a single NUMA socket, per-VM throughput remained consistent across the cluster, evidence that adding nodes scales Oracle performance proportionally. ()

Note: Results are not comparable to published TPC-C results and do not comply with TPC-C benchmark standards.

Performance Details and Results

HammerDB 5.0 is an open-source database transactional load-testing and benchmarking tool. The OLTP workload is derived from the TPC-C benchmark standard, however it is not comparable to published TPC-C results and does not comply with TPC-C benchmark standards.

Testing used HammerDB instances running locally on each Oracle database VM (loopback connections), eliminating the remote driver-VM network bottleneck. Testing was performed on a four-node ThinkAgile VX650 V4 cluster running eight Oracle database VMs.

The following table lists the configuration used in the testing. Testing used the ThinkAgile VX650 V4 (model 7DG6CTO1WW); the ThinkAgile FX650 V4 (model 7DPMCTO1WW) is a validated alternative.

Table 4. TPC-C performance testing hardware configuration

Component	**Details**
Server	4 x Lenovo ThinkAgile VX650 V4 (Machine Type: 7DG6CTO1WW)
CPU	2 sockets, Intel Xeon 6747P (Granite Rapids), 48 cores/socket
RAM	1.5TB DDR5 per node (16 x 96GB Lenovo TruDDR5 6400 MT/s)
Network Adapter	Mellanox ConnectX-6 Lx 10/25GbE SFP28 2-port OCP Ethernet Adapter
Disks (vSAN ESA)	8 x Micron 1.92TB 2.5-inch NVMe SSD (7500 PRO) per node
Disks (Boot/OS)	2 x Micron 480GB M.2 NVMe SSD (RAID 1) per node
Hypervisor	VMware ESXi 9.0.0 build 24755229
HCI Software	VMware Cloud Foundation (VCF) 9.0, vSAN ESA
Oracle Database	Oracle Database 23ai Enterprise Edition Release 23.26.1.0.0
UEFI Version	1.20 (Build ID: IHE110U)
BMC Version	1.22 (Build ID: IHX414J)
HammerDB	5.0
Guest OS	Oracle Linux 9.7 (kernel 6.12.0-105.51.5)

The following table lists the TPC-C performance testing details and results.

Table 5. TPC-C performance testing details and results

Parameter	**Value**
VM Configuration	48 vCPU, 512GB memory per VM
Number of VMs per host	2 (1 per NUMA socket)
Disk - OS Boot	1 x 128GB
Disk - Swap	1 x 128GB
Disk - Datafiles (/oradata)	6 x 101GB (LVM, 606GB total, XFS)
Disk - Redo Logs (/oraredo1-6)	6 x 200GB (ext4, 180GB per group)
Disk - Oracle Binaries (/u01)	1 x 200GB (XFS)
Number of warehouses	500
Virtual users per VM	250
allwarehouses	false (home-warehouse mode)
Ramp-up	5 minutes
Test duration	10 minutes
Driver method	Local (HammerDB on each dbnode, loopback)
Total TPM (8 VMs)	36.8M
Average TPM per VM	~4.6M

The following table lists the Oracle Database instance parameters.

Table 6. Oracle Database instance parameters

Parameter	Value
sga_target	0 (disabled - manual SGA sizing)
sga_max_size	420G
db_cache_size	350G
db_16k_cache_size	16G
shared_pool_size	40G
large_pool_size	2G
pga_aggregate_target	80G
log_buffer	1073741824 (1GB)
db_writer_processes	16
use_large_pages	ONLY
commit_wait	NOWAIT
commit_logging	BATCH
filesystemio_options	SETALL
fast_start_mttr_target	0
log_checkpoint_interval	0
log_checkpoint_timeout	0
undo_retention	900
parallel_max_servers	640
parallel_min_servers	0
processes	1000
open_cursors	800

Across the eight Oracle Database 23ai VMs, the cluster sustained an aggregate **36.8 million TPM**, averaging approximately **4.6 million TPM per VM**. Because each VM was pinned to a single NUMA socket with local CPU and memory, per-VM throughput remained consistent across the cluster, confirming that the NUMA-aligned placement strategy eliminated cross-socket memory latency as a bottleneck and that adding nodes scales Oracle performance proportionally.

Business Outcome

Deploying Oracle Database 23ai on Lenovo ThinkAgile VX and FX V4 with VCF delivers measurable business value:

- **Proven, linear performance:** each of the eight Oracle Database 23ai VMs sustained approximately 4.6 million HammerDB TPM, for an aggregate 36.8 million TPM on a single four-node cluster. This near-linear scaling lets customers consolidate multiple databases onto fewer nodes, add capacity proportionally as demand grows, and reduce the number of Oracle-licensed cores needed for a given workload, while all-NVMe vSAN ESA keeps latency low and predictable under sustained OLTP load. (HammerDB OLTP is derived from the TPC-C standard; results are not comparable to published TPC-C benchmarks.)
- **Non-disruptive growth:** Capacity is added by inserting nodes into the running cluster, with no application downtime, data migration, or forklift upgrades, so scaling the Oracle estate becomes a routine operational step rather than a re-architecture project.
- **Lower operational overhead:** A single software-defined platform with centralized lifecycle management reduces administrative effort and accelerates time-to-production.

- **Simplified, single-vendor support:** Lenovo ThinkAgile Premier Support provides one point of contact for hardware, VMware software, and services, eliminating multi-vendor escalation delays.
- **Investment protection:** FX650 V4 multi-hypervisor flexibility lets organizations change HCI software direction without replacing hardware.

Best Practices for Oracle Deployment

The following best practices were applied in the validated configuration and are recommended for production Oracle Database 23ai deployments on ThinkAgile VX and FX V4.

- **BIOS Configuration:** Set the BIOS/UEFI operating mode to Maximum Performance on all nodes. Disable energy-saving features such as C-states and frequency scaling to ensure consistent CPU performance under sustained database workloads.
- **VM Sizing and NUMA Alignment:** Configure each Oracle VM with a vCPU count matching the physical core count of one NUMA socket. Use VM-Host affinity rules in vSphere DRS to enforce strict host pinning so each Oracle VM runs exclusively on its designated host and NUMA socket, keeping all scheduling and memory allocation local.
- **SGA Sizing:** Size the Oracle SGA to accommodate the active working set in memory, maximizing buffer cache hit rates and minimizing physical I/O against vSAN-backed storage under OLTP workloads.
- **Storage Layout:** Use separate virtual disks for Oracle datafiles, redo logs, and binaries, each assigned to independent SCSI controllers, to maximize parallel I/O throughput and prevent contention between redo log and datafile activity.
- **Redo Log Configuration:** Configure an adequate number of redo log groups per node, sized for the expected redo generation rate. Place each redo log group on a dedicated virtual disk on a separate controller to prevent I/O contention between log writes and datafile operations.
- **Commit and Checkpoint Optimization:** Tune Oracle commit and checkpoint parameters to optimize group-commit behavior for OLTP throughput. Disabling automatic checkpoint tuning reduces background I/O overhead and delivers consistent foreground transaction performance.
- **I/O Configuration:** Enable asynchronous and direct I/O for all Oracle datafiles, and configure an appropriate number of database writer processes to maximize parallel write throughput from the buffer cache to vSAN-backed storage.
- **vSphere HA Configuration:** Disable vSphere HA VM Monitoring for Oracle database VMs. Under sustained high-CPU workloads, VMware Tools heartbeat responses may be delayed, triggering false-positive VM resets that interrupt database operations.
- **Tablespace Pre-allocation:** Pre-allocate datafile sizes to the expected workload rather than relying on auto-extend. Use bigfile tablespaces for application schemas, and multiple Undo datafiles for high-concurrency workloads, to improve I/O predictability and prevent space exhaustion.
- **Performance Monitoring:** Use Oracle ADDM and AWR to analyze performance between test runs and identify bottlenecks. Schedule AWR snapshots outside active measurement windows to avoid interfering with results.

Bill of Materials

The following table details a single ThinkAgile VX650 V4 node (model 7DG6CTO1WW). For a ThinkAgile FX650 V4 node, use model 7DPMCTO1WW as the base unit instead.

Table 7. Bill of Materials

Part Number	Product Description	Quantity
7DG6CTO1WW	Lenovo ThinkAgile VX650 V4 (dual-socket, 2U)	1
C68E	ThinkAgile VX650 V4 24x2.5-inch Chassis	1
C5R8	Intel Xeon 6747P 48C 330W 2.7GHz Processor	2
C3QR	ThinkSystem 2U V4 Performance Heatsink	2
BZ7D	ThinkSystem 96GB TruDDR5 6400MHz (2Rx4) RDIMM	16
C26V	ThinkSystem M.2 RAID B545i-2i SATA/NVMe Adapter	1
C2BR	ThinkSystem 2.5-inch U.3 7500 PRO 1.92TB RI NVMe PCIe 4.0 x4 HS SSD	8
C46P	ThinkSystem 2U V4 8x2.5-inch NVMe Gen5 Backplane	1
CGH5	ThinkSystem M.2 PM9D3a 480GB RI NVMe PCIe 5.0 x4 NHS SSD	2
AUZV	ThinkSystem Broadcom 5719 1GbE RJ45 4-port OCP Ethernet Adapter	1
BE4T	ThinkSystem Mellanox ConnectX-6 Lx 10/25GbE SFP28 2-port OCP Ethernet Adapter	1
C62D	ThinkSystem SR650 V4 x16 PCIe Gen5 Riser	1
C0UC	ThinkSystem 2700W 230V Titanium CRPS Premium Hot-Swap Power Supply	2
C3RD	ThinkSystem SR650a V4 Performance Fan Module option kit	6
C1YR	ThinkSystem 1U/2U V4 USB Ports Extension Board	1
C2DH	ThinkSystem Toolless Slide Rail Kit V4	1
SCJD	XClarity One - Standard, Per Endpoint w/ 3-Yr SW S&S	1
BPKR	TPM 2.0	1
B3XQ	Solution Level Warranty Period (3 yr)	1
BVGL	Data Center Environment 30C / 86F	1

Conclusion

Lenovo ThinkAgile VX and FX V4 with VMware Cloud Foundation provide a validated, high-performance foundation for Oracle Database 23ai. The tested configuration delivered 36.8 million transactions per minute across eight VMs on a single four-node cluster while preserving the operational simplicity of a hyperconverged, software-defined platform.

By combining Intel Xeon 6 processors, all-NVMe vSAN ESA storage, NUMA-aware VM placement, and the tuning practices in this brief, organizations can consolidate demanding Oracle workloads with predictable performance and linear scalability.

With Lenovo ThinkAgile Premier Support providing a single point of contact for hardware, VMware software, and services, IT teams can deploy and operate Oracle on VCF with reduced risk and lower operational overhead.

Why Lenovo

Lenovo is a global technology leader delivering the infrastructure that powers mission-critical enterprise workloads worldwide. ThinkAgile VX and FX V4 systems are factory-integrated and pre-validated with VMware software and deployment services, giving customers a fast, low-risk path to a production Oracle platform. Backed by Lenovo ThinkAgile Premier Support and a broad services portfolio, Lenovo helps organizations deploy, operate, and scale Oracle Database 23ai with confidence.

For More Information

To learn more about running Oracle Database 23ai on Lenovo ThinkAgile VX and FX V4, contact your Lenovo representative or Lenovo Business Partner, or visit the resources below.

References:

- Lenovo ThinkAgile VX650 V4 Product Guide
  https://lenovopress.lenovo.com/lp2134-lenovo-thinkagile-vx650-v4-hyperconverged-system
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  https://docs.oracle.com/en/database/oracle/oracle-database/23/
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Related product families

Product families related to this document are the following:

- Intel Alliance
- Oracle database
- ThinkAgile FX Series
- ThinkAgile VX Series for VMware
- VMware Alliance

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