Dell Inc.

TPC Express Benchmark™ AI
Full Disclosure Report

Dell EMC PowerEdge R6625

with 1x PowerEdge R6625; 10x PowerEdge R6625
using

Cloudera SEL Data Platform Private Cloud Base Edition

running on

Red Hat Enterprise Linux 8.6/8.7

TPCx-AI Version	1.0.2
Report Edition	First
Report Submitted	June 13, 2023

First Edition - June 2023

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Abstract

Dell conducted the TPC Express Benchmark™ AI (TPCx-AI) on the Dell EMC PowerEdge R6625. The software used included Cloudera SEL Data Platform Private Cloud Base Edition. This report provides full disclosure of the results. All testing was conducted in conformance with the requirements of the TPCx-AI Standard Specification, Revision 1.0.2.

Configuration Overview

Test Sponsor	Node(s)	Operating System
Dell	1x PowerEdge R6625 (Master Node) 10x PowerEdge R6625 (Worker Node)	Red Hat Enterprise Linux 8.6/8.7

Metrics Overview

Total System Cost	Performance	Price/Performance	Availability Date
$872,988 USD	3,258.01 AIUCpm@1000	267.96 USD $/AIUCpm@1000	June 13, 2023

Executive Summary

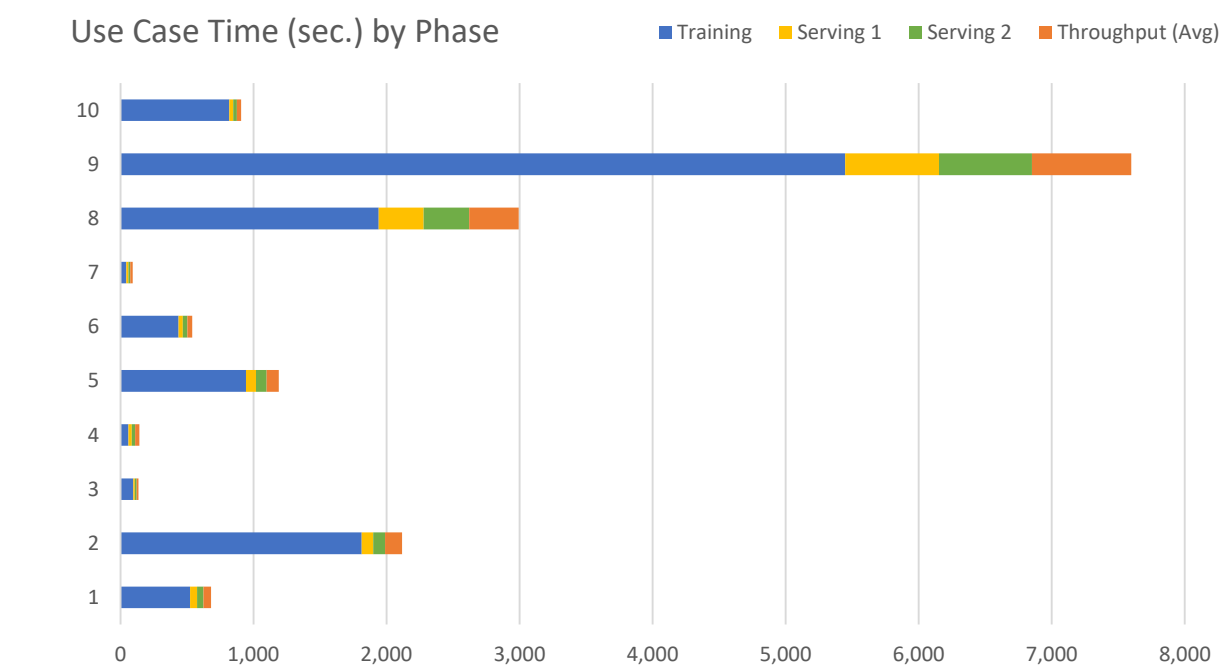
The Executive Summary follows on the next several pages.

Dell EMC PowerEdge R6625

TPCx-AI	1.0.2
TPC Pricing	2.8.0
Report Date	Jun. 13, 2023

TPCx-AI Performance	Total System Cost	Price/Performance	Availability Date
3,258.01 AIUCpm@1000	**$872,988 USD**	**$267.96 USD/AIUCpm@1000**	**June 13, 2023**

Framework	Operating System	Other Software	Scale Factor	Streams
Cloudera SEL Data Platform Private Cloud Base Edition	Red Hat Enterprise Linux 8.6/8.7	N/A	1,000	4



Physical Storage / Scale Factor	Scale Factor / Physical Memory	Main Data Redundancy Model
214.56	0.12	Replication3, RAID 1

Servers: Total Processors/Cores/Threads	11 22 / 704 / 1,344

Server Type	1x PowerEdge R6625 (Master Node)	10x PowerEdge R6625 (Worker Node)
Processors	2x AMD EPYC 9354 32-Core Processor	2x AMD EPYC 9354 32-Core Processor
Memory	768 GiB	768 GiB
Storage Controller	1x PERC H755 RAID Controller	1x PERC H755 RAID Controller
Storage Device	1x 800 GB SAS SSD 1x 960 GB SAS SSD 2x Dell Ent. 1.92 TB NVMe	2x 800 GB SAS SSD (7 nodes) 2x 960 GB SAS SSD (3 nodes) 4x 3.84 TB SAS SSD (all nodes) 2x Dell Ent. 1.92 TB NVMe (all nodes)
Network Controller	1x Broadcom Adv. Dual 25 Gb	1x Broadcom Adv. Dual 25 Gb
Connectivity	1x Mellanox SN3420 100/25 GbE (Cluster Interconnect)	

DELL EMC	Dell EMC PowerEdge R6625	TPCx-AI	1.0.2
		TPC Pricing	2.8.0
		Report Date	Jun. 13, 2023

Description	Part Number	Source	List Price	Qty	Extended Price	1-Yr. Maintenance
Hardware						
PowerEdge R6625 Server - Primary Node	210-BFXO	1	$90,673.91	1	$90,673.91	
2.5" Chassis with up to 10 SAS4/SATA Drives including 4 Universal Slots, Front PERC 11	321-BIIO	1	$0.00	1		
SAS/SATA/NVMe Capable Backplane	379-BDSW	1	$0.00	1		
No Rear Storage	379-BDTE					
No GPU Enablement	379-BDSR					
Trusted Platform Module 2.0 V3	461-AAIG	1	$0.00	1		
AMD EPYC 9354 3.25GHz, 32C/64T, 256M Cache (280W) DDR5-4800	338-CGXN	1	$0.00	1		
Additional Processor Selected	379-BDCO	1	$0.00	1		
Heatsink for 2 CPU configuration	412-ABEE	1	$0.00	1		
Performance Optimized	370-AHLL	1	$0.00	1		
4800MT/s RDIMMs	370-AHCL	1	$0.00	1		
32GB RDIMM, 4800MT/s Dual Rank	370-AGZP	1	$0.00	24		
Unconfigured RAID	780-BCDS	1	$0.00	1		
PERC H755 SAS Front	405-AAZB	1	$0.00	1		
Front PERC Mechanical Parts, rear load	750-ADRI	1	$0.00	1		
800GB SSD SAS ISE, MU, up to 24Gbps 512e 2.5in Hot-Plug, AG Drive	345-BEPV	1	$0.00	1		
960GB SSD vSAS 12Gbps SED RI 512e 2.5in Hot-plug 1WPD	345-BHXD	1	$0.00	1		
1.92TB Enterprise NVMe Read Intensive AG Drive U.2 Gen4 with carrier	400-BKGW	1	$0.00	2		
Performance BIOS Settings	384-BBBL	1	$0.00	1		
UEFI BIOS Boot Mode with GPT Partition	800-BBDM	1	$0.00	1		
High Performance Fan x4	384-BDHQ	1	$0.00	1		
Single, Hot-plug, Power Supply Non-Redundant (1+0), 1400W, Mixed Mode	450-AIQW	1	$0.00	1		
C13 to C14, PDU Style, 12 AMP, 6.5 Feet (2m) Power Cord, North America	492-BBDI	1	$0.00	2		
Riser Config 1, 1 x16 LP + 2 x16 LP	330-BCCX	1	$0.00	1		
PowerEdge R6625 Motherboard	329-BHQD	1	$0.00	1		
Broadcom 57414 Dual Port 10/25GbE SFP28, OCP NIC 3.0	540-BCOC	1	$0.00	1		
Broadcom 5720 Dual Port 1GbE Optional LOM	540-BDKD	1	$0.00	1		
TRAY,W/LBLS,X8/X10,R6625	321-BIGJ	1	$0.00	1		
No Bezel	350-BBBW	1	$0.00	1		
BOSS Blank	403-BCID	1	$0.00	1		
Enterprise Linux OS, Non Factory Installed, Requires Subscription Selection	605-BBFL	1	$0.00	1		
No Media Required	605-BBFN	1	$0.00	1		
RHEL, 1-2SKT, Physical Node, 3YR Premium Sub, 1 Virtual Guest, Digitally Fulfilled	528-CHFH	1	$0.00	1		
iDRAC9, Enterprise 16G	528-CTIC	1	$0.00	1		
Secured Component Verification	528-COYT	1	$0.00	1		
No Quick Sync	350-BBXM	1	$0.00	1		
iDRAC,Factory Generated Password	379-BCSF	1	$0.00	1		
iDRAC Group Manager, Disabled	379-BCQY	1	$0.00	1		
ReadyRails Sliding Rails Without Cable Management Arm or Strain Relief Bar	770-BECD	1	$0.00	1		
No Systems Documentation, No OpenManage DVD Kit	631-AACK	1	$0.00	1		
PowerEdge R6625 Shipping	340-DDEC	1	$10.00	1	$10.00	
PowerEdge R6625 Shipping Material 4	340-DDCC	1	$99.00	1	$99.00	
PowerEdge R6625 CCC Marking, No CE Marking	470-AFOR	1	$0.00	1		
Basic Next Business Day 36 Months	709-BBFM	1	$186.76	1		$186.76
ProSupport and Next Business Day Onsite Service Initial, 36 Month(s)	865-BBMY	1	$8,559.30	1		$8,559.30

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DELL EMC	Dell EMC PowerEdge R6625	TPCx-AI	1.0.2
		TPC Pricing	2.8.0
		Report Date	Jun. 13, 2023

(continued from the previous page)

Description	Part Number	Source	List Price	Qty	Extended Price	1-Yr. Maintenance
PowerEdge R6625 Server - Worker Nodes Type 1	210-BFXO	1	$117,263.33	3	$351,789.99	
2.5 Chassis	379-BDTF	1	$0.00	3	$0.00	
SAS/SATA/NVMe Capable Backplane	379-BDSW	1	$0.00	3	$0.00	
No Rear Storage	379-BDTE	1	$0.00	3	$0.00	
No GPU Enablement	379-BDSR	1	$0.00	3	$0.00	
Trusted Platform Module 2.0 V3	461-AAIG	1	$0.00	3	$0.00	
2.5" Chassis with up to 10 SAS4/SATA Drives including 4 Universal Slots, Front PERC 11	321-BIIO	1	$0.00	3	$0.00	
AMD EPYC 9354 3.25GHz, 32C/64T, 256M Cache (280W) DDR5-4800	338-CGXN	1	$0.00	3	$0.00	
Additional Processor Selected	379-BDCO	1	$0.00	3	$0.00	
Heatsink for 2 CPU configuration	412-ABEE	1	$0.00	3	$0.00	
Performance Optimized	370-AHLL	1	$0.00	3	$0.00	
4800MT/s RDIMMs	370-AHCL	1	$0.00	3	$0.00	
32GB RDIMM, 4800MT/s Dual Rank	370-AGZP	1	$0.00	72	$0.00	
Unconfigured RAID	780-BCDS	1	$0.00	3	$0.00	
PERC H755 SAS Front	405-AAZB	1	$0.00	3	$0.00	
Front PERC Mechanical Parts, rear load	750-ADRI	1	$0.00	3	$0.00	
960GB SSD vSAS 12Gbps SED RI 512e 2.5in Hot-plug 1WPD	345-BHXD	1	$0.00	6	$0.00	
3.84TB SSD vSAS Mixed Use 12Gbps 512e 2.5in Hot-Plug ,AG Drive SED, 3DWPD	345-BCVR	1	$0.00	12	$0.00	
1.92TB Enterprise NVMe Read Intensive AG Drive U.2 Gen4 with carrier	400-BKGW	1	$0.00	6	$0.00	
Performance BIOS Settings	384-BBBL	1	$0.00	3	$0.00	
UEFI BIOS Boot Mode with GPT Partition	800-BBDM	1	$0.00	3	$0.00	
High Performance Fan x4	384-BDHQ	1	$0.00	3	$0.00	
Dual, Hot-plug, Power Supply Redundant (1+1), 1400W, Mixed Mode, NAF	450-AIQZ	1	$0.00	3	$0.00	
C13 to C14, PDU Style, 12 AMP, 6.5 Feet (2m) Power Cord, North America	492-BBDI	1	$0.00	6	$0.00	
Riser Config 1, 1 x16 LP + 2 x16 LP	330-BCCX	1	$0.00	3	$0.00	
PowerEdge R6625 Motherboard	329-BHQD	1	$0.00	3	$0.00	
Broadcom 57414 Dual Port 10/25GbE SFP28, OCP NIC 3.0	540-BCOC	1	$0.00	3	$0.00	
Broadcom 5720 Dual Port 1GbE Optional LOM	540-BDKD	1	$0.00	3	$0.00	
TRAY,W/LBLS,X8/X10,R6625	321-BIGJ	1	$0.00	3	$0.00	
No Bezel	350-BBBW	1	$0.00	3	$0.00	
BOSS Blank	403-BCID	1	$0.00	3	$0.00	
Enterprise Linux OS, Non Factory Installed, Requires Subscription Selection	605-BBFL	1	$0.00	3	$0.00	
No Media Required	605-BBFN	1	$0.00	3	$0.00	
RHEL, 1-2SKT, Physical Node, 3YR Premium Sub, 1 Virtual Guest, Digitally Fulfilled	528-CHFH	1	$0.00	3	$0.00	
iDRAC9, Enterprise 16G	528-CTIC	1	$0.00	3	$0.00	
Secured Component Verification	528-COYT	1	$0.00	3	$0.00	
No Quick Sync	350-BBXM	1	$0.00	3	$0.00	
iDRAC,Factory Generated Password	379-BCSF	1	$0.00	3	$0.00	
iDRAC Group Manager, Disabled	379-BCQY	1	$0.00	3	$0.00	
ReadyRails Sliding Rails Without Cable Management Arm or Strain Relief Bar	770-BECD	1	$0.00	3	$0.00	
No Systems Documentation, No OpenManage DVD Kit	631-AACK	1	$0.00	3	$0.00	
PowerEdge R6625 Shipping	340-DDEC	1	$0.00	3	$0.00	
PowerEdge R6625 Shipping Material 4	340-DDCC	1	$0.00	3	$0.00	
PowerEdge R6625 CCC Marking, No CE Marking	470-AFOR	1	$0.00	3	$0.00	
Basic Next Business Day 36 Months	709-BBFM	1	$186.76	3		$560.28
ProSupport and Next Business Day Onsite Service Initial, 36 Month(s)	865-BBMY	1	$8,559.30	3		$25,677.90

(continued on the next page)

DELL EMC	Dell EMC PowerEdge R6625	TPCx-AI	1.0.2
		TPC Pricing	2.8.0
		Report Date	Jun. 13, 2023

(continued from the previous page)

Description	Part Number	Source	List Price	Qty	Extended Price	1-Yr. Maintenance
PowerEdge R6625 Server - Worker Nodes Type 2	210-BFXO	1	$118,791.37	7	$831,539.59	
2.5 Chassis	379-BDTF	1		7	$0.00	
SAS/SATA/NVMe Capable Backplane	379-BDSW	1		7	$0.00	
No Rear Storage	379-BDTE	1		7	$0.00	
No GPU Enablement	379-BDSR	1		7	$0.00	
Trusted Platform Module 2.0 V3	461-AAIG	1		7	$0.00	
2.5" Chassis with up to 10 SAS4/SATA Drives including 4 Universal Slots, Front PERC 11	321-BIIO	1		7	$0.00	
AMD EPYC 9354 3.25GHz, 32C/64T, 256M Cache (280W) DDR5-4800	338-CGXN	1		7	$0.00	
Additional Processor Selected	379-BDCO	1		7	$0.00	
Heatsink for 2 CPU configuration	412-ABEE	1		7	$0.00	
Performance Optimized	370-AHLL	1		7	$0.00	
4800MT/s RDIMMs	370-AHCL	1		7	$0.00	
32GB RDIMM, 4800MT/s Dual Rank	370-AGZP	1		168	$0.00	
Unconfigured RAID	780-BCDS	1		7	$0.00	
PERC H755 SAS Front	405-AAZB	1		7	$0.00	
Front PERC Mechanical Parts, rear load	750-ADRI	1		7	$0.00	
SanDisk 16GB Ultra Flair USB 3.0 Flash Drive	SDCZ73-016G-G46	3	$7.49	3	$22.47	
800GB SSD SAS ISE, MU, up to 24Gbps 512e 2.5in Hot-Plug, AG Drive	345-BEPV	1		14	$0.00	
3.84TB SSD vSAS Mixed Use 12Gbps 512e 2.5in Hot-Plug ,AG Drive SED, 3DWPD	345-BCVR	1S		28	$0.00	
1.92TB Enterprise NVMe Read Intensive AG Drive U.2 Gen4 with carrier	400-BKGW	1		14	$0.00	
Performance BIOS Settings	384-BBBL	1		7	$0.00	
UEFI BIOS Boot Mode with GPT Partition	800-BBDM	1		7	$0.00	
High Performance Fan x4	384-BDHQ	1		7	$0.00	
Dual, Hot-plug, Power Supply Redundant (1+1), 1400W, Mixed Mode, NAF	450-AIQZ	1		7	$0.00	
C13 to C14, PDU Style, 12 AMP, 6.5 Feet (2m) Power Cord, North America	492-BBDI	1		14	$0.00	
Riser Config 1, 1 x16 LP + 2 x16 LP	330-BCCX	1		7	$0.00	
PowerEdge R6625 Motherboard	329-BHQD	1		7	$0.00	
Broadcom 57414 Dual Port 10/25GbE SFP28, OCP NIC 3.0	540-BCOC	1		7	$0.00	
Broadcom 5720 Dual Port 1GbE Optional LOM	540-BDKD	1		7	$0.00	
TRAY,W/LBLS,X8/X10,R6625	321-BIGJ	1		7	$0.00	
No Bezel	350-BBBW	1		7	$0.00	
BOSS Blank	403-BCID	1		7	$0.00	
Enterprise Linux OS, Non Factory Installed, Requires Subscription Selection	605-BBFL	1		7	$0.00	
No Media Required	605-BBFN	1		7	$0.00	
RHEL, 1-2SKT, Physical Node, 3YR Premium Sub, 1 Virtual Guest, Digitally Fulfilled	528-CHFH	1		7	$0.00	
iDRAC9, Enterprise 16G	528-CTIC	1		7	$0.00	
Secured Component Verification	528-COYT	1		7	$0.00	
No Quick Sync	350-BBXM	1		7	$0.00	
iDRAC,Factory Generated Password	379-BCSF	1		7	$0.00	
iDRAC Group Manager, Disabled	379-BCQY	1		7	$0.00	
ReadyRails Sliding Rails Without Cable Management Arm or Strain Relief Bar	770-BECD	1		7	$0.00	
No Systems Documentation, No OpenManage DVD Kit	631-AACK	1		7	$0.00	
PowerEdge R6625 Shipping	340-DDEC	1		7	$0.00	
PowerEdge R6625 Shipping Material 4	340-DDCC	1		7	$0.00	
PowerEdge R6625 CCC Marking, No CE Marking	470-AFOR	1		7		
Basic Next Business Day 36 Months	709-BBFM	1	$186.76	7		$1,307.32
ProSupport and Next Business Day Onsite Service Initial, 36 Month(s)	865-BBMY	1	$8,559.30	7		$59,915.10
Keyboard and Optical Mouse, USB, Black, English	570-AAKV, 580-ADJC	1	$12.00	1	$12.00	
Dell 24 Monitor	210-AIWG	1	$169.99	1	$169.99	
Mellanox MSN3420-CB2F 25GbE/100GbE Switch	920-9N213-00F7-0X0	2	$16,661.00	1	$16,661.00	
NVIDIA ENT Business Critical Support ServNVIDIA ENT Business Critical Support Services 4HR On-Site CE for SN3420 - 12.0 Months	780-C34N4Z+P2CMI12	2	$2,667.00	1		$2,667.00
				Subtotal	**$1,290,977.95**	**$98,873.66**

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DELL EMC	Dell EMC PowerEdge R6625	TPCx-AI	1.0.2
		TPC Pricing	2.8.0
		Report Date	Jun. 13, 2023

(continued from the previous page)

Description	Part Number	Source	List Price	Qty	Extended Price	1-Yr. Maintenance
Cloudera SEL Data Platform Private Cloud Base Edition, Annual Subscription per compute node, Business Level Support	AB242979	1	$15,000.00	1	$15,000.00	
Cloudera SEL Data Platform Private Cloud Base Edition, Annual Subscription per storage node, Business Level Support	AB352445	1	$15,229.50	10	$152,295.00	
RHEL, 1-2SKT, Physical Node, 1YR Premium Sub, 1 Virtual Guest, Digitally Fulfilled	528-CHFJ	1	$1,299.00	11	$14,289.00	
				Subtotal	**$181,584.00**	**$0.00**
				Total	**$1,472,561.95**	**$98,873.66**
				Large Purchase Discount (45%)*	**-$655,155.43**	**-$43,293.00**

Pricing: 1 = Dell; 2 = NVIDIA; 3 = Amazon

* Discount applies to all line items where Key = 1. Discount based upon total system cost as purchased by a regular customer.

S: One or more components of the measured configuration have been substituted in the priced configuration. See the FDR for details.

Audited by Doug Johnson, InfoSizing

Total System Cost (USD):	**$872,988**
AIUCpm@1000:	**3,258.01**
$/AIUCpm@1000:	**$267.96**

Prices used in TPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated Line Items. Individually negotiated discounts are not permitted. Special prices based on assumptions about past or future purchases are not permitted. All discounts reflect standard pricing policies for the listed Line Items. For complete details, see the pricing section of the TPC Benchmark Standard. If you find that the stated prices are not available according to these terms, please inform the TPC at pricing@tpc.org. Thank you.

Dell EMC PowerEdge R6625

TPCx-AI	1.0.2
TPC Pricing	2.8.0
Report Date	Jun. 13, 2023

Numerical Quantities

AIUCpm@1000	**3,258.01**	T_{Load}	927.49
Scale Factor	1,000	T_{LD}	927.49
Streams	4	T_{PTT}	492.14
		T_{PST1}	57.00
Kit Version	1.0.2	T_{PST2}	57.36
Execution Status	Pass	T_{PST}	57.36
Accuracy Status	Pass	T_{TT}	43.93

Test Times

Overall Run Start Time	2023-06-07 22:35:25.028
Overall Run End Time	2023-06-08 04:20:10.222
Overall Run Elapsed Time	20,685.194
Load Test Start Time	2023-06-07 23:17:13.748
Load Test End Time	2023-06-07 23:32:43.409
Load Test Elapsed Time	929.661
Power Training Start Time	2023-06-07 23:32:43.411
Power Training End Time	2023-06-08 02:54:56.659
Power Training Elapsed Time	12,133.248
Power Serving 1 Start Time	2023-06-08 02:54:56.662
Power Serving 1 End Time	2023-06-08 03:17:56.895
Power Serving 1 Elapsed Time	1,380.233
Power Serving 2 Start Time	2023-06-08 03:17:56.898
Power Serving 2 End Time	2023-06-08 03:41:00.813
Power Serving 2 Elapsed Time	1,383.915
Scoring Start Time	2023-06-08 03:45:30.011
Scoring End Time	2023-06-08 03:50:41.962
Scoring Elapsed Time	311.951
Throughput Start Time	2023-06-08 03:50:41.966
Throughput End Time	2023-06-08 04:20:10.221
Throughput Elapsed Time	1,768.255

DELL EMC	Dell EMC PowerEdge R6625	TPCx-AI	1.0.2
		TPC Pricing	2.8.0
		Report Date	Jun. 13, 2023

Numerical Quantities (continued)

Use Case Times & Accuracy

Use Case	Training (sec)	Serving 1 (sec)	Serving 2 (sec)	Throughput (avg)	Accuracy
UC01	523.703	51.215	49.736	56.083	0.000
UC02	1,813.764	85.354	88.783	129.274	0.438
UC03	95.795	12.443	12.811	13.840	4.575
UC04	59.080	25.475	25.489	31.016	0.712
UC05	943.023	76.289	78.351	91.615	0.033
UC06	435.865	33.135	33.071	37.121	0.214
UC07	43.585	15.317	15.300	17.143	1.653
UC08	1,940.283	338.579	341.811	372.418	0.750
UC09	5,448.735	703.291	699.631	745.458	1.000
UC10	818.635	28.326	28.190	31.162	0.817

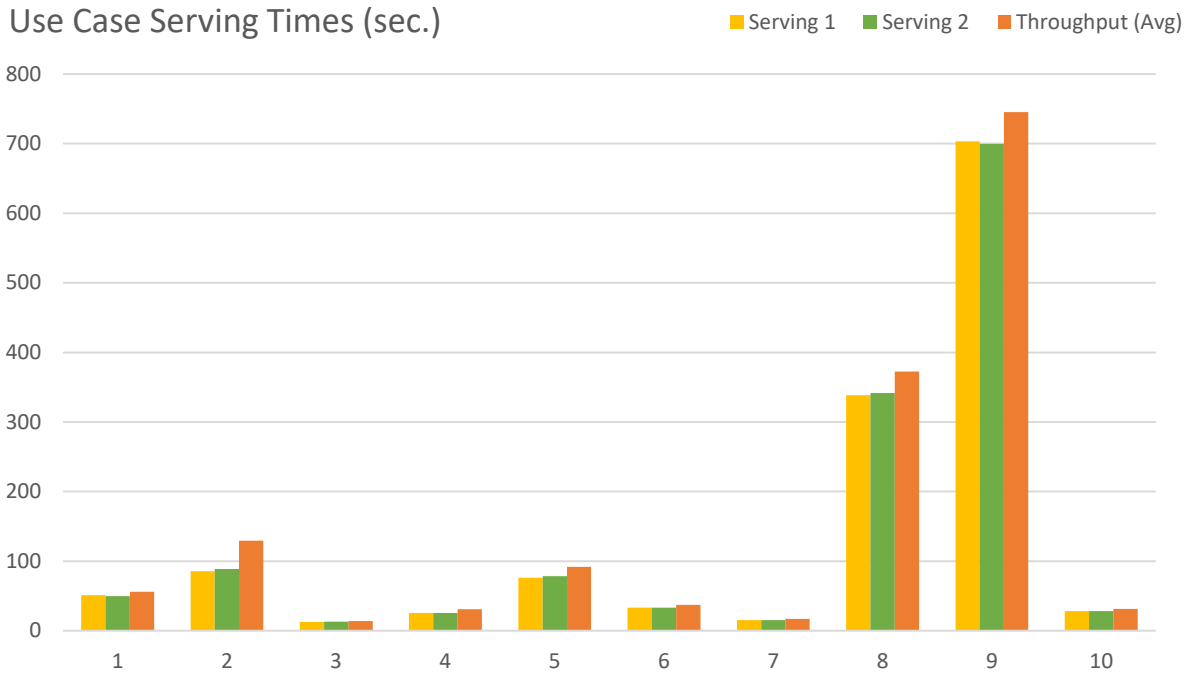


Table of Contents

Abstract 3
Executive Summary 3
Table of Contents 11
Clause 0 – Preamble 13
0.1 TPC Express Benchmark™ AI Overview 13
Clause 1 – General Items 15
1.1 Test Sponsor 15
1.2 Parameter Settings 15
1.3 Configuration Diagrams 15
1.3.1 Measured Configuration 16
1.3.2 Differences Between the Measured and the Priced Configurations 16
Clause 2 – SW Components & Data Distribution 17
2.1 Roles and Dataset Distribution 17
2.2 File System Implementation 18
2.3 Execution Engine, Frameworks, Driver & Libraries 18
2.4 Applied Patches 18
Clause 3 – Workload Related Items 19
3.1 Hardware & Software Tuning 19
3.2 Kit Version & Modifications 19
3.3 Use Case Elapsed Times 19
3.4 SUT Validation Test Output 20
3.5 Configuration Parameters 21
Clause 4 – SUT Related Items 22
4.1 Specialized Hardware/Software 22
4.2 Configuration Files 22
4.3 SUT Environment Information 22
4.4 Data Storage to Scale Factor Ratio 22
4.5 Scale Factor to Memory Ratio 22
4.6 Output of Tests 22
4.7 Additional Sponsor Files 22
4.8 Model Optimizations 23
Clause 5 – Metrics and Scale Factor 23
5.1 Reported Performance Metrics 23

5.2 Throughput Test Stream Times....24
Auditor's Information....25
Third-Party Price Quotes....28
NVIDIA....28
Amazon....29
Supporting Files Index....30

Clause 0 – Preamble

0.1 TPC Express Benchmark™ AI Overview

Artificial intelligence (AI) has become a key transformational technology of our times. Advances in neural networks and other machine learning techniques have made it possible to use AI on a variety of use cases. From the public sector to aerospace, defense and academia, new and improved ways to use AI techniques are changing the way we harness data and analytics. This along with advances in compute, interconnect and memory technologies have made possible to solve complicated challenges that will ultimately benefit customers in production datacenter and cloud environments.

Abundant volumes of rich data from text, images, audio and video are the essential starting point for creating a benchmark that would represent the myriad of use cases and customers. TPC Express Benchmark™ AI (TPCx-AI) is created in keeping with the TPC tradition of emulating real world AI scenarios and data science use cases. Unlike most other AI benchmarks, the TPCx-AI uses a diverse dataset and is able to scale across a wide range of scale factors. TPCx-AI may later expand with additional use cases and add additional flexibility for a greater variety of implementations.

The benchmark defines and provides a means to evaluate the System Under Test (SUT) performance as a general-purpose data science system that:

- Generates and processes large volumes of data.
- Trains preprocessed data to produce realistic machine learning models.
- Conducts accurate insights for real-world customer scenarios based on the generated models.
- Can scale to large scale distributed configurations.
- Allows for flexibility in configuration changes to meet the demands of the dynamic AI landscape.

The benchmark models real-life examples of companies and public-sector organizations that use a range of analytics techniques, both AI and more traditional machine learning approaches, as well as the potential application of these techniques in situations like those in which they have already been successfully deployed. In addition, the benchmark measures end to end time to provide insights for individual use cases, as well as throughput metrics to simulate multiuser environments for a given hardware, operating system, and data processing system configuration under a controlled, complex, multi-user AI or machine learning data science workload.

The purpose of TPC benchmarks is to provide relevant, objective performance data to industry users. To achieve that purpose, TPC benchmark specifications require benchmark runs be implemented with systems, products, technologies and pricing that:

- Are generally available to users.
- Are relevant to the market segment that the individual TPC benchmark models or represents (e.g., TPCx-AI models and represents complex, high data volume, decision support environments).
- Would plausibly be implemented.

The TPCx-AI kit is available from the TPC website (see www.tpc.org/tpcx-ai/ for more information). Users must sign up and agree to the TPCx-AI End User Licensing Agreement (EULA) to download the kit. All related work (such as collaterals, papers, derivatives) must acknowledge the TPC and include the TPCx-AI copyright. The TPCx-AI kit includes: TPCx-AI Specification document (this document), TPCx-AI Users Guide (README.md) documentation, scripts to set up the benchmark environment, code to execute the benchmark workload, Data Generator, use case related files, and Benchmark Driver.

The use of new systems, products, technologies (hardware or software) and pricing is encouraged so long as they meet the requirements above. Specifically prohibited are benchmark systems, products, technologies or pricing (hereafter referred to as "implementations") whose primary purpose is performance optimization of TPC benchmark results without any corresponding applicability to real-world applications and environments. In other words, all "benchmark special" implementations that improve benchmark results but not real-world performance or pricing, are prohibited.

The rules for pricing are included in the TPC Pricing Specification.

Further information is available at www.tpc.org.

Clause 1 – General Items

1.1 Test Sponsor

This benchmark was sponsored by Dell Inc..

1.2 Parameter Settings

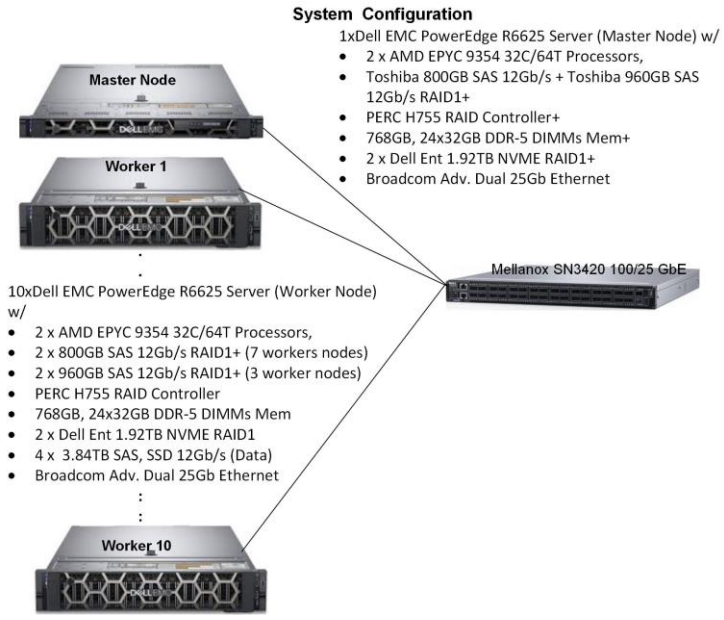
The Supporting Files Archive contains the parameters and options used to configure the components involved in this benchmark.

1.3 Configuration Diagrams

The measured configuration diagram is shown below. In addition, any differences between the measured and the priced configurations are described.

1.3.1 Measured Configuration

Nodes:	11		
Processors/Cores/Threads:	22/704/1,344	Storage Devices:	84
Total Memory:	8,448 GiB	Storage Capacity:	214,560 GB



	Master Node	Worker Node
Server	1x PowerEdge R6625:	10x PowerEdge R6625:
Procs/Cores/Threads:	2/32/64	2/32/64
Processor Model:	2x AMD EPYC 9354 32-Core Processor	2x AMD EPYC 9354 32-Core Processor
Memory:	768 GiB	768 GiB
Storage Controller:	1x PERC H755 RAID Controller	1x PERC H755 RAID Controller
Storage Devices:	1x 800 GB SAS SSD 1x 960 GB SAS SSD 2x Dell Ent. 1.92 TB NVMe	2x 800 GB SAS SSD (7 nodes) 2x 960 GB SAS SSD (3 nodes) 2x Dell Ent. 1.92 TB NVMe 4x 3.84 TB SAS SSD
Network Controller:	1x Broadcom Adv. Dual 25 Gb	1x Broadcom Adv. Dual 25 Gb
Network:	1x Mellanox SN3420 100/25 GbE (Cluster Interconnect);	

The distribution of software components over server nodes is detailed in Clause 2.

1.3.2 Differences Between the Measured and the Priced Configurations

Node dn5 had three 3.2 TB SAS SSDs in the measured configuration that were substituted with three 3.84 TB SAS SSDs in the priced configuration.

Clause 2 – SW Components & Data Distribution

2.1 Roles and Dataset Distribution

Table 2-1 describes the distribution of the dataset across all media in the SUT.

Server	Host Name	Storage	Contents
1x PowerEdge R6625 Master Node	genoa-masternode alias nn	1x 800 GB SAS SSD 1x Toshiba 960 GB SAS 2x Dell Ent. 1.92 TB NVMe	OS
10x PowerEdge R6625 Worker Nodes	genoadatanode [1-10] alias dn[1-10]	2x 800 GB SAS SSD (7 nodes) 2x 960 GB SAS SSD (3 nodes) 4x 3.84 TB SAS SSD (9 nodes) 1x 3.84 TB SAS SSD (1 node) 3x 3.2 TB SAS SSD (1 node) 2x Dell Ent. 1.92 TB NVMe	OS OS Distributed FS Distributed FS Distributed FS Kit & Metadata

Server	Host Name	SW Services
1x PowerEdge R6625 Master Node	genoa-masternode alias nn	Core Configuration Gateway Core Configuration Storage operations HDFS Balancer HDFS NameNode HDFS SecondaryNameNode Hive Gateway Hive Metastore Server Hive on Tez Gateway Hive on Tez HiveServer2 Cloudera Management Service Reports Manager Cloudera Management Service Alert Publisher Cloudera Management Service Alert Publisher Cloudera Management Service Event Server Cloudera Management Service Host Monitor Cloudera Management Service Monitor YARN Queue Manager Store YARN Queue Manager Webapp Spark Gateway Spark History Server Tez Gateway YARN JobHistory Server YARN ResourceManager ZooKeeper Server
10x PowerEdge R6625 Worker Nodes	genoadatanode [1-10] alias dn[1-10]	Core Configuration Gateway HDFS DataNode Hive Gateway Hive on Tez Gateway Spark Gateway Tez Gateway YARN NodeManager

Table 2-1 Software Components and Dataset Distribution

2.2 File System Implementation

A distributed file system provided by Red Hat Enterprise Linux 8.6/8.7 / Cloudera SEL Data Platform Private Cloud Base Edition was used for data generation and the Load Test. The data set was not relocated after generation and before the Load Test.

2.3 Execution Engine, Frameworks, Driver & Libraries

Cloudera SEL Data Platform Private Cloud Base Edition consisted of the following components.

Component	Version
HDFS	3.1.1
YARN	3.1.1
MapReduce2	3.1.1
Spar	2.4.7

Table 2-2 Software Components

For a detailed listing of installed libraries, please see the envInfo logs in the Supporting Files.

2.4 Applied Patches

No additional vendor-supported patches were applied to the SUT.

Clause 3 – Workload Related Items

3.1 Hardware & Software Tuning

The Supporting Files archive contains all hardware and software configuration scripts.

3.2 Kit Version & Modifications

Table 3-1 shows the version of the TPCx-AI used to produce this result along with any kit flies that were modified to facilitate system, platform, and framework differences.

TPCx-AI Kit Version	1.0.2
Modified File tools/parallel-data-load.sh See Auditor's Note	Description of Changes Enable concurrent file upload.

Table 3-1 Kit Version & Modifications

3.3 Use Case Elapsed Times

Below are the elapsed times for each use case. Use cases are grouped based on whether they use Deep Learning or Machine Learning techniques.

Type	UC ID	P1	P2	T1	T2	T3	T4
Deep Learning	2	85.354	88.783	84.456	218.882	106.819	106.940
	5	76.289	78.351	92.814	86.072	89.711	97.864
	9	703.291	699.631	737.822	735.672	753.781	754.556
Machine Learning	1	51.215	49.736	56.067	51.839	58.496	57.931
	3	12.443	12.811	12.862	16.521	13.181	12.794
	4	25.475	25.489	28.904	32.305	32.087	30.769
	6	33.135	33.071	37.541	41.387	33.342	36.212
	7	15.317	15.300	17.125	17.160	16.828	17.460
	8	338.579	341.811	388.931	528.033	286.091	286.618
	10	28.326	28.190	30.293	29.474	31.987	32.895

Table 3-2 Use Case Elapsed Times

3.4 SUT Validation Test Output

Validation Run Report

AIUCpm@1	15.88	T_{Load}	275.18
Scale Factor	1	T_{LD}	275.18
Streams	4	T_{PTT}	57.69
		T_{PST1}	21.40
Kit Version	1.0.2	T_{PST2}	21.02
Execution Status	Pass	T_{PST}	21.40
Accuracy Status	Pass	T_{TT}	6.00

Test Times

Overall Run Start Time	2023-06-07 21:37:42.914
Overall Run End Time	2023-06-07 22:32:21.292
Overall Run Elapsed Time	3,278.378
Load Test Start Time	2023-06-07 21:41:19.468
Load Test End Time	2023-06-07 21:45:56.770
Load Test Elapsed Time	277.302
Power Training Start Time	2023-06-07 21:45:56.771
Power Training End Time	2023-06-07 22:11:02.962
Power Training Elapsed Time	1,506.191
Power Serving 1 Start Time	2023-06-07 22:11:02.965
Power Serving 1 End Time	2023-06-07 22:15:08.982
Power Serving 1 Elapsed Time	246.017
Power Serving 2 Start Time	2023-06-07 22:15:08.984
Power Serving 2 End Time	2023-06-07 22:19:14.435
Power Serving 2 Elapsed Time	245.451
Scoring Start Time	2023-06-07 22:23:41.596
Scoring End Time	2023-06-07 22:28:10.631
Scoring Elapsed Time	269.035
Throughput Start Time	2023-06-07 22:28:10.635
Throughput End Time	2023-06-07 22:32:21.291
Throughput Elapsed Time	250.656

(continued on next page)

Validation Run Report (continued)

Accuracy Metrics

Use Case	Metric Name	Metric	Criteria	Threshold	Status
1	N/A	0.000	N/A	0.00	Pass
2	word_error_rate	0.445	<=	0.50	Pass
3	mean_squared_log_error	5.803	<=	5.40	Fail*
4	f1_score	0.697	>=	0.65	Pass
5	mean_squared_log_error	0.088	<=	0.50	Pass
6	matthews_corrcoef	0.233	>=	0.19	Pass
7	median_absolute_error	1.715	<=	1.80	Pass
8	accuracy_score	0.701	>=	0.65	Pass
9	accuracy_score	1.000	>=	0.90	Pass
10	accuracy_score	0.817	>=	0.70	Pass

*Because of the small dataset size used for the Validation Test, Spark-based implementations may not be able to satisfy the accuracy threshold for Use Case 3. The TPCx-AI Subcommittee is aware of this issue and has decided that this failure does not invalidate the test.

3.5 Configuration Parameters

The Supporting Files archive contains all Global Benchmark Parameter and Use Case Specific Parameter settings.

Clause 4 – SUT Related Items

4.1 Specialized Hardware/Software

No Specialized Hardware/Software was used in the SUT.

4.2 Configuration Files

The Supporting Files archive contains all configuration files.

4.3 SUT Environment Information

All envInfo.log files are included in the Supporting Files archive.

4.4 Data Storage to Scale Factor Ratio

The details of the Data Storage Ratio are provided below.

Node Count	Disks	Size (GB)	Total (GB)
1	1	800	800
1	1	960	960
1	2	1,920	3,840
7	2	800	11,200
3	2	960	5,760
10	2	1,920	38,400
10	4	3,840	153,600

Total Storage (GB)	214,560
Scale Factor	1,000
Data Storage Ratio	214.56

4.5 Scale Factor to Memory Ratio

The details of the Memory to Scale Factor Ratio are provided below.

Nodes	Memory (GiB)	Total (GiB)
11	768	8,448

Scale Factor	1,000
Total Memory (GiB)	8,448
SF / Memory Ratio	0.12

4.6 Output of Tests

The Supporting Files archive contains the output files of all tests.

4.7 Additional Sponsor Files

The Supporting Files archive contains any additional files that were used.

4.8 Model Optimizations

The Supporting Files archive contains any model optimization files that were used.

Clause 5 – Metrics and Scale Factor

5.1 Reported Performance Metrics

Metric Overview

TPCx-AI Performance Metric	3,258.01	AIUCpm@1000
TPCx-AI Price/Performance Metric	267.96	$/AIUCpm@1000
TPCx-AI Scale Factor	1,000	
TPCx-AI Stream Count	4	

Test Times

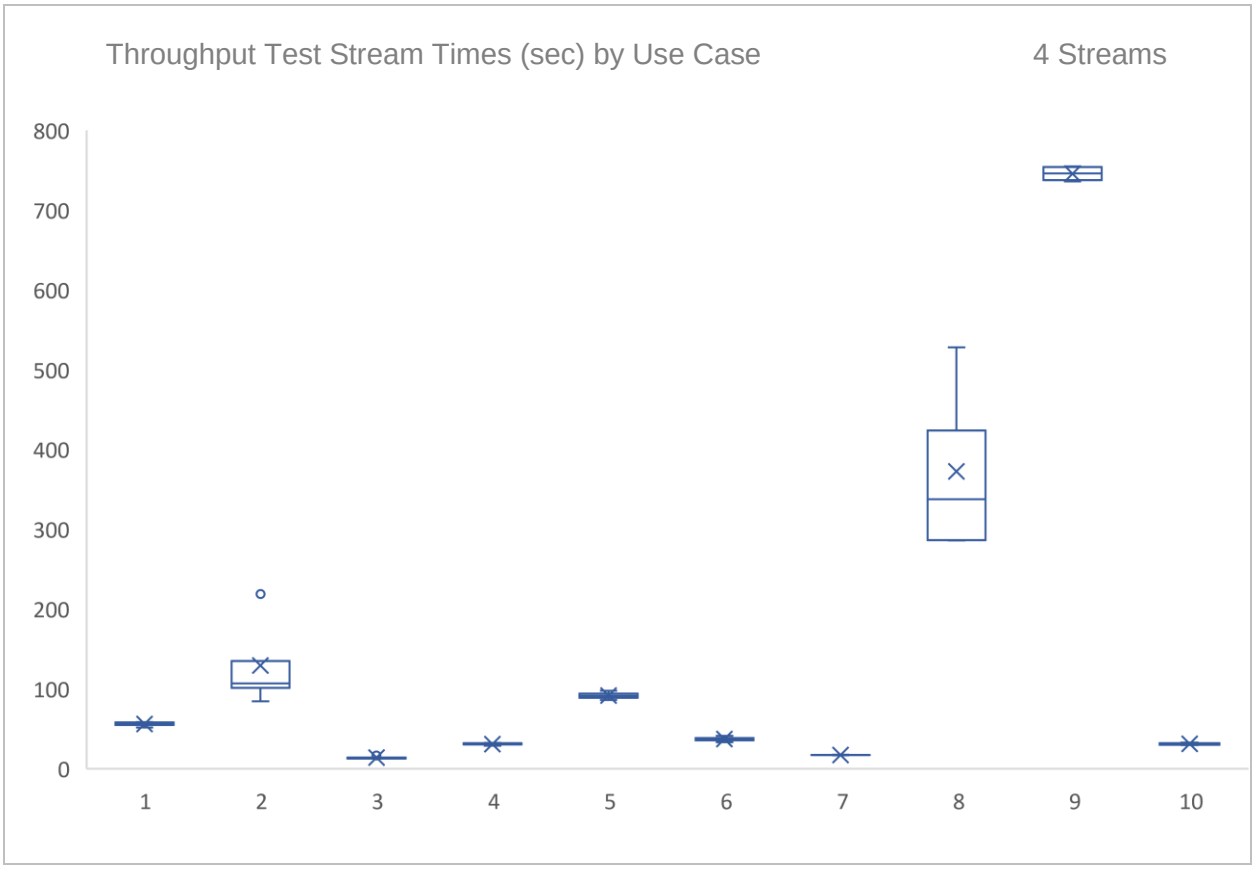
Overall Run Start Time	2023-06-07 22:35:25.028
Overall Run End Time	2023-06-08 04:20:10.222
Overall Run Elapsed Time	20,685.194
Load Test Start Time	2023-06-07 23:17:13.748
Load Test End Time	2023-06-07 23:32:43.409
Load Test Elapsed Time	929.661
Power Training Start Time	2023-06-07 23:32:43.411
Power Training End Time	2023-06-08 02:54:56.659
Power Training Elapsed Time	12,133.248
Power Serving 1 Start Time	2023-06-08 02:54:56.662
Power Serving 1 End Time	2023-06-08 03:17:56.895
Power Serving 1 Elapsed Time	1,380.233
Power Serving 2 Start Time	2023-06-08 03:17:56.898
Power Serving 2 End Time	2023-06-08 03:41:00.813
Power Serving 2 Elapsed Time	1,383.915
Scoring Start Time	2023-06-08 03:45:30.011
Scoring End Time	2023-06-08 03:50:41.962
Scoring Elapsed Time	311.951
Throughput Start Time	2023-06-08 03:50:41.966
Throughput End Time	2023-06-08 04:20:10.221
Throughput Elapsed Time	1,768.255

Accuracy Metrics

Use Case	Metric Name	Metric	Criteria	Threshold	Status
1	N/A	0.000	N/A	0.00	Pass
2	word_error_rate	0.438	<=	0.50	Pass
3	mean_squared_log_error	4.575	<=	5.40	Pass
4	f1_score	0.712	>=	0.65	Pass
5	mean_squared_log_error	0.033	<=	0.50	Pass
6	matthews_corrcoef	0.214	>=	0.19	Pass
7	median_absolute_error	1.653	<=	1.80	Pass
8	accuracy_score	0.750	>=	0.65	Pass
9	accuracy_score	1.000	>=	0.90	Pass
10	accuracy_score	0.817	>=	0.70	Pass

5.2 Throughput Test Stream Times

The following chart shows the minimum, 1st quartile, median, mean (X), 3rd quartile, and maximum stream times by use case for the Throughput Test. Outliers are marked with “o”.



Auditor's Information

This benchmark was audited by Doug Johnson, InfoSizing.

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63 Lourdes Drive
Leominster, MA 01453
978-343-6562.

This benchmark's Full Disclosure Report can be downloaded from www.tpc.org.

A copy of the auditor's attestation letter is included in the next two pages.

InfoSizing
The Right Metric For Sizing IT

TPC
Certified Auditor

Nicholas Wakou
Dell Inc.
701 E. Parmer Ln. Bld. 2
Austin, TX 78753

June 12, 2023

I verified the TPC Express Benchmark™ AI v1.0.2 performance of the following configuration:

Platform:	1x PowerEdge R6625; 10x PowerEdge R6625
Operating System:	Red Hat Enterprise Linux 8.6 / 8.7
Additional Software:	Cloudera SEL Data Platform Private Cloud Base Edition

The results were:

Performance Metric	**3,258.01 AIUCpm@10000**	
Secondary Metrics	T_{LD}	927.49
	T_{PTT}	492.14
	T_{PST}	57.36
	T_{TT}	43.93

System Under Test	**1x PowerEdge R6625; 10x PowerEdge R6625 with:**		
CPUs	2x AMD EPYC 9354 32-Core Processor (all nodes)		
Memory	768 GiB (all nodes)		
Storage	***Qty***	***Size***	***Type***
	1	800 GB	SAS SSD (master node)
	1	960 GB	SAS SSC (master node)
	2	1.92 TB	NVMe (master node)
	2	800 GB	SAS SSD (7 worker nodes)
	2	960 GB	SAS SSD (7 worker nodes)
	2	1.92 TB	NVMe (all worker nodes)
	4	3.84 TB	SAS SSD (9 worker nodes)
	1	3.84 TB	SAS SSD (1 worker node)
	3	3.2 TB	SAS SSD (1 worker node)

In my opinion, these performance results were produced in compliance with the TPC requirements for the benchmark.

The following verification items were given special attention:

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- All TPC-provided components were verified to be v1.0.2.
- All checksums were validated for compliance.
- Any modifications to shell scripts were reviewed for compliance.
- No modifications were made to any of the Java code.
- The generated dataset was properly scaled to 1,000 GB.
- The generated dataset used for testing was protected by Replication 3 & RAID 1.
- The elapsed times for all phases and runs were correctly measured and reported.
- The Storage and Memory Ratios were correctly calculated and reported.
- The system pricing was verified for major components and maintenance.
- The major pages from the FDR were verified for accuracy.

Additional Audit Notes:

Because of the small dataset size used for the Validation Test, this Spark-based implementation was not able to satisfy the accuracy threshold for Use Case 3. The TPCx-AI Subcommittee is aware of this issue and has decided that this failure does not invalidate the test.

Two files were erroneously reported as having incorrect checksums. This is due to a minor issue in the TPC-provided kit. The TPCx-AI Subcommittee is aware of this and will correct it in a future release of the kit.

The measured configuration included three 3.2 TB SAS SSDs that were substituted by three 3.84 SAS SSDs in the priced configuration. Based on the specifications of these disks, it is my opinion that this substitution has no significant effect on performance.

One worker node had one 16 GB USB drive in it during testing. This drive (and 2 spares) is included in the pricing per TPC rules. However, this drive was not utilized during testing and had no effect on performance.

Respectfully Yours,

Doug Johnson, Certified TPC Auditor

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Third-Party Price Quotes

NVIDIA

Date: 6/12/2023
Quote # Q-979786
Opportunity # O-313351
Expiration Date 9/10/2023

Advanced Micro Devices (AMD)

Pricing Request Type

NPN Solution Provider
Direct

End Customer
Advanced Micro Devices (AMD)
United States

NVIDIA Salesperson
Martin McNarney
mcnarney@nvidia.com

Qty	Part Number	Reference Part Number	Description	Term (Year)	Unit Price	Discount (%)	Sale Price	Total
1	920-9N213-00F7-0X0	MSN3420-CB2F	NVIDIA Spectrum-2 based 25GbE/100GbE 1U Open Ethernet switch with Onyx, 48 SFP28 ports and 12 QSFP28 ports, 2 Power Supplies (AC), x86 CPU, shor t depth, P2C airflow, Rail Kit		$16,661.00	0.00	$16,661.00	$16,661.00
1	780-C34N4Z +P2CMI12		NVIDIA ENT Business Critical Support Services 4HR On-Site CE for SN3420 - 12.0 Months	1	$2,667.00	0.00	$2,667.00	$2,667.00

Net Total $19,328.00

NOTES

- All pricing is in USD and subject to change. Pricing does not include currency conversion fees, taxes or VAT, and other considerations that may affect the final price that you pay.
- Purchase Order Receipt Date AND Customer Request Date (CRD) must be earlier than Quote expiration date.
- Distributor Purchase Order to NVIDIA:
  - Quote number listed in this document must be included and can only be used for one unique order and may not be used in any other orders.
  - All products, quantities, pricing, reseller and end customer information must align with those on the referenced, valid quote.
  - Reseller, Reseller Contact, End Customer information
  - Must include full company name with no acronyms or abbreviations, address, first and last name of the product end customer contact, and a valid email address with a domain that matches the company name.
- Please reference your NVIDIA Price List for all ordering rules.
- This document serves as a pricing information to the Distributor.
- This quotation is subject to the terms and conditions specified in the applicable signed agreement between NVIDIA and Partner. In the absence of such signed agreement, NVIDIA's Standard Terms & Conditions will apply.
- Accordingly, the products are offered under the applicable terms and conditions, and this quotation is expressly conditional on acceptance of such terms and conditions. No additional or conflicting terms and conditions will apply without NVIDIA's prior, express written consent, and any such additional or conflicting terms and conditions on partner's purchase order, acknowledgement or other business form are hereby rejected by NVIDIA.

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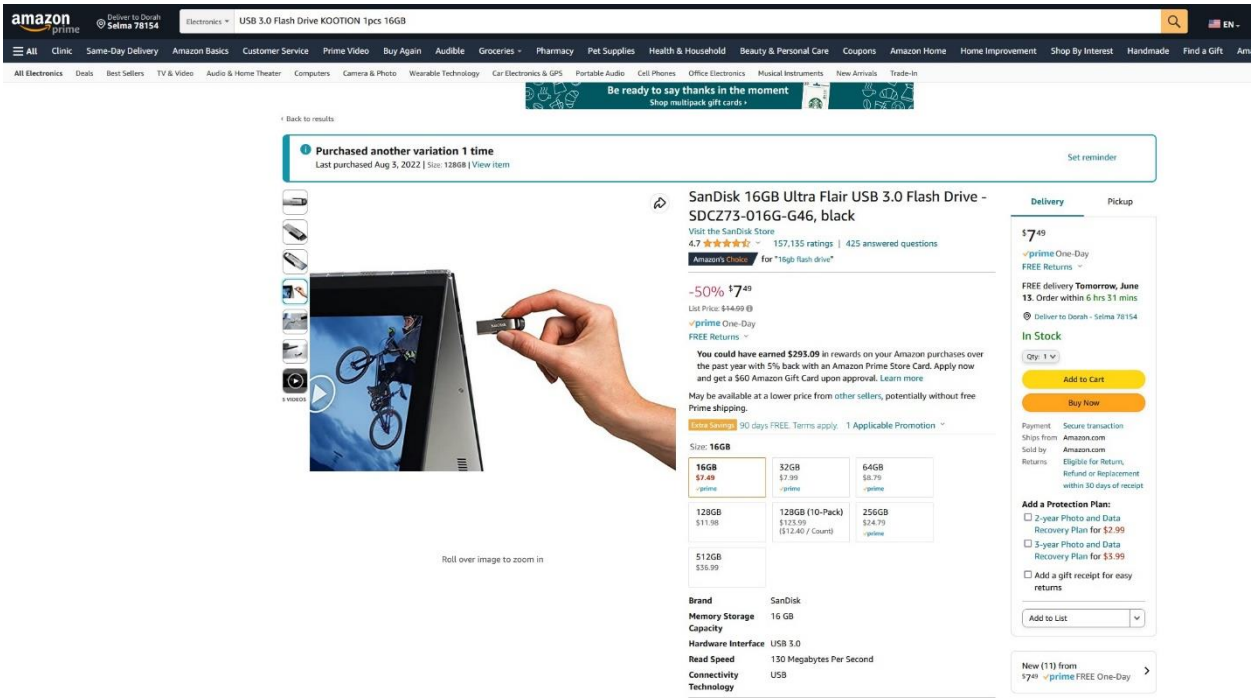
Amazon


USB 3.0 Flash Drive KOOTION 1pcs 16GB
Be ready to say thanks in the moment
Shop multipack gift cards
Purchased another variation 1 time
Last purchased Aug 3, 2022 | Size: 128GB | View item
Set reminder
SanDisk 16GB Ultra Flair USB 3.0 Flash Drive - SDCZ73-016G-G46, black
Visit the SanDisk Store
4.7 157,135 ratings | 425 answered questions
Amazon's Choice for "16gb flash drive"
-50% $7.49
List Price: $14.69
prime One-Day
FREE Returns
You could have earned $293.09 in rewards on your Amazon purchases over the past year with 5% back with an Amazon Prime Store Card. Apply now and get a $60 Amazon Gift Card upon approval. Learn more
May be available at a lower price from other sellers, potentially without free Prime shipping.
Extra Savings 90 days FREE. Terms apply. 1 Applicable Promotion
Size: 16GB
16GB $7.49
32GB $7.99
64GB $8.79
128GB $11.98
128GB (10-Pack) $123.99 ($12.40 / Count)
256GB $24.79
512GB $36.99
Brand SanDisk
Memory Storage Capacity 16 GB
Hardware Interface USB 3.0
Read Speed 130 Megabytes Per Second
Connectivity Technology USB
Roll over image to zoom in
Delivery
Pickup
$7.49
prime One-Day
FREE Returns
FREE delivery Tomorrow, June 13. Order within 6 hrs 31 mins
Deliver to Dorah - Selma 78154
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Qty: 1
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Payment Secure transaction
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Sold by Amazon.com
Returns Eligible for Return, Refund or Replacement within 30 days of receipt
Add a Protection Plan:
2-year Photo and Data Recovery Plan for $2.99
3-year Photo and Data Recovery Plan for $3.99
Add a gift receipt for easy returns
Add to List
New (11) from $7.49 prime FREE One-Day

Supporting Files Index

The Supporting Files archive for this disclosure contains the following structure.

Supporting Files Directory	Description
CheckIntegrity/…	Output of CHECK_INTEGRITY test (if the phase is not done as part of the Validation and Performance Test).
PerformanceTest/…	Performance Test output files.
ValidationTest/…	Validation Test output files.

Additional files used by Dell	
Sponsor/ModelOptimization/…	Details of model optimization.
Sponsor/ModifiedKitFiles/…	1 modified file(s).
Sponsor/Tuning/…	All tuning files used.