TPC Benchmark™ H
Full Disclosure Report

First Edition
1–Feb–2024

Using
Microsoft SQL Server 2019 Enterprise Edition

on
SYSGEARSYSM50CYP2UR208_6334
First Edition: February 2024

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Benchmark results are highly dependent upon workload, specific application requirements, and system design and implementation. Relative system performance will vary as a result of these and other factors. Therefore, the TPC Benchmark™ H should not be used as a substitute for a specific customer application benchmark when critical capacity planning and/or product evaluation decisions are contemplated.

All performance data contained in this report was obtained in a rigorously controlled environment. Results obtained in other operating environments may vary significantly. No warranty of system performance or price/performance is expressed or implied in this report.

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Abstract

This report documents the methodology and results of the TPC Benchmark™ H (TPC-H) test conducted by TTA on Microsoft SQL Server 2019 Enterprise Edition on SYSGEAR M50CYP2UR208_6334.

Note that the Microsoft SQL Server 2019 was installed on the Virtual Machine run on SYSGEAR M50CYP2UR208_6334. The Virtual Machine is powered by SEMS software, which is a Software Defined Memory Solution produced by SYSGEAR Inc.

Microsoft SQL Server 2019 Enterprise Edition on SYSGEAR M50CYP2UR208_6334

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<th>Company Name</th>
<th>System Name</th>
<th>Database Software</th>
<th>Operating System</th>
</tr>
</thead>
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<tr>
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<td>SYSGEAR M50CYP2UR208_6334</td>
<td>Microsoft SQL Server 2019 Enterprise Edition (64bit)</td>
<td>RedHat Enterprise Linux 7.3</td>
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TPC Benchmark™ H Metrics

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<th>Total System Cost</th>
<th>Composite Metric</th>
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<th>Availability Date</th>
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<td>839,991.10₩/kQphH@3,000GB</td>
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<td>Composite Query per Hour Metric</td>
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**Database Load Time = 00d 08h 30m 33s**

**Storage Redundancy Level**
- Load included backup: Y
- Base Tables and Auxiliary Data Structures, DBMS Temporary Space: No RAID
- Total Data Storage/Database Size = 17.04
- OS and DBMS Software: No RAID
- Memory/Database Size = 68.3%

**System Components**
- Nodes: 1
- Intel(R) Xeon(R) Gold 6334 CPU @ 3.60GHz: 2
  - Cores/Threads: 16/32
- Memory: 2.048 GiB
- 4TB NVMe Drives: 7
- 3.84TB SAS SSD: 7
- Total Storage: 54.88 TB (51,110.98 GiB)
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<th>Qty</th>
<th>Price(W)</th>
<th>3-Yr. Maint. Price(W)</th>
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* All discounts are based on Korea list prices and for similar quantities and configurations. Discounts for similarly sized configurations will be similar to those quoted here, but may vary based on the components in the configuration.

**Pricing Key**

1) SYSGEAR Inc. 2) RockPlace Inc.

All of the prices are based on South Korea’s currency, KRW (W, Korean Won) and excluded VAT.

Benchmark implementation and results independently audited by Doug Johnson of InfoSizing (www.sizing.com)
Prices used in TPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated components. 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 components. For complete details, see the pricing sections of the TPC benchmark pricing specifications. If you find that the stated prices are not available according to these terms, please inform the TPC at pricing@tpc.org. Thank you.
Measurement Results:

- Database Scale Factor = 3,000GB
- Total Data Storage / Database Size = 17.04
- Start of database load time = 2023-12-07 9:37:55 AM
- End of database load time = 2023-12-07 6:08:28 PM
- Database Load Time = 00d 08h 30m 33s
- Query Streams for Throughput Test = 8
- TPC-H Power = 312,243.4
- TPC-H Throughput = 105,442,4
- TPC-H Composite Query-per-Hour Rating (QphH@3,000GB) = 181,448.9
- Total System Price Over 3 Years (W, KRW) = 158,573,900
- TPC-H Price/Performance Metric (W/kQphH@3,000GB) = 839,991.10

Measurement Intervals:

- Measurement Interval in Throughput Test (Ts) = 18,026.91 seconds

### Duration of Stream Execution:

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<th>RF1 Start Time</th>
<th>RF1 End Time</th>
<th>RF2 Start Time</th>
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Microsoft SQL Server 2019  
on SYSGEAR  
M50CYP2UR208_6334  

TPC-H Rev. 3.0.1  
TPC-Pricing Rev. 2.9.0  

Report Date:  
Feb 1, 2024  

Query Execution Times (Query1~Query12):  

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<th>Q9</th>
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Q1 Avg  159.54  42.19  683.88  603.04  857.14  7.41  430.18  578.64  2,509.62  419.96  68.25  192.79  
Q1 Max  196.02  74.81  823.17  798.42  1,042.84  9.33  520.26  690.30  2,975.85  586.92  97.14  271.29  

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<td>66.41</td>
<td>207.08</td>
<td>2,289.07</td>
<td>260.14</td>
<td>45.62</td>
<td>182.54</td>
</tr>
</tbody>
</table>

Q1 Min  178.34  8.94  6.60  65.50  14.89  246.18  6.31  18.36  203.98  31.82  44.25  152.28  
Q1 Avg  1,559.93| 81.33| 51.65| 531.31| 168.33| 2,770.32| 60.50| 179.72| 2,261.58| 284.25| 45.31| 172.47  
Q1 Max  1,922.30| 116.07| 85.54| 666.46| 250.11| 3,303.83| 84.08| 221.00| 2,808.38| 371.62| 46.75| 189.33  

TPC-H Full Disclosure Report  
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TPC Benchmark H Overview

The TPC Benchmark™ H (TPC-H) is a Decision Support benchmark. It is a suite of business-oriented ad-hoc queries and concurrent modifications. The queries and the data populating the database have been chosen to have broad industry-wide relevance while maintaining a sufficient degree of ease of implementation. This benchmark illustrates Decision Support systems that:

- Examine large volumes of data
- Execute queries with a high degree of complexity
- Give answers to critical business questions

TPC-H evaluates the performance of various Decision Support systems by the execution of sets of queries against a standard database under controlled conditions. The TPC-H queries:

- Give answers to real-world business questions
- Simulate generated ad-hoc queries
- Are far more complex than most OLTP transactions
- Include a rich breadth of operators and selectivity constraints
- Generate intensive activity on the part of the database server component of the system under test
- Are executed against a database complying to specific population and scaling requirements
- Are implemented with constraints derived from staying closely synchronized with an on-line production database
0. General Items

0.1 Benchmark Sponsor

A statement identifying the benchmark sponsor(s) and other participating companies must be provided.

This benchmark was sponsored by Telecommunications Technology Association (TTA). The implementation was developed and engineered in partnership with Microsoft Corp. and SYSGEAR Inc.

0.2 Parameter Settings

Settings must be provided for all customer-tunable parameters and options that have been changed from the defaults found in actual products, including but not limited to:

- Database Tuning Options
- Optimizer/Query execution options
- Query processing tool/language configuration parameters
- Recovery/commit options
- Consistency/locking options
- Operating system and configuration parameters
- Configuration parameters and options for any other software component incorporated into the pricing structure
- Compiler optimization options

This requirement can be satisfied by providing a full list of all parameters and options, as long as all those which have been modified from their default values have been clearly identified and these parameters and options are only set once.

The Supporting Files Archive contains the database and OS parameters used in this benchmark.

0.3 Configuration Diagrams

Diagrams of both measured and priced configurations must be provided, accompanied by a description of the differences. This includes, but is not limited to:

- Number and type of processors.
- Size of allocated memory, and any specific mapping/partitioning of memory unique to the test.
- Number and type of disk units (and controllers, if applicable).
- Number of channels or bus connections to disk units, including their protocol type.
- Number of LAN (e.g. Ethernet) Connections, including routers, workstations, terminals, etc., that were physically used in the test or are incorporated into the pricing structure.
- Type and the run-time execution location of software components (e.g., DBMS, query processing tools/languages, middle-ware components, software drivers, etc.).

The configuration diagram for both the tested and priced system is depicted in Figure 0.1. There is no difference between the priced and tested configurations.
Figure 0.1: Benchmarked and Priced Configuration

**Database Server**

**Physical Machine:**
1 x SYSGEAR M50CYP2UR208_6334  
2 – Intel® Xeon® Gold 6334 CPU @3.60GHz  
8/16 cores/threads per processor, 18M Cache  
2 TiB Main memory  
7 x 3.84 TB 12Gbps SAS SSD  
7 x 4 TB NVMe SSD

**Virtual Machine:**
1 x SYSALIGN.SEMS (Software Defined Memory Solution)  
1 – Intel® Xeon® Gold 6334 CPU @3.60GHz  
30 cores/thread  
3 TiB Main memory  
1 x 3.84 TB 12Gbps SAS SSD (OS Disk – RAID 0)  
4 x 3.84 TB 12Gbps SAS SSD (Log Disk – RAID 10)  
2 x 3.84 TB 12Gbps SAS SSD (Backup Disk – RAID 0)  
3 x 4 TB NVMe SSD (Data Disk)  
RedHat Enterprise Linux 7.3  
Microsoft SQL Server 2019 Enterprise Edition
Clause 1: Logical Database Design

1.1 Database Definition Statements

*Listings must be provided for all table definition statements and all other statements used to set up the test and qualification databases.*

The Supporting Files Archive contains the build scripts that create, populate, index and analyze the tables for the TPC-H database.

1.2 Physical Organization

*The physical organization of tables and indices within the test and qualification databases must be disclosed. If the column ordering of any table is different from that specified in Clause 1.4, it must be noted.*

No column reordering was used.

1.3 Horizontal Partitioning

*Horizontal partitioning of tables and rows in the test and qualification databases (see Clause 1.5.4) must be disclosed.*

Horizontal partitioning is used on LINEITEM and ORDERS tables and the partitioning columns are L_SHIPDATE and O_ORDERDATE. The partition granularity is by week.

1.4 Replication

*Any replication of physical objects must be disclosed and must conform to the requirements of Clause 1.5.7.*

No replication was used.
Clause 2: Queries and Refresh Functions

2.1 Query Language

The query language used to implement the queries must be identified.

SQL was the query language used.

2.2 Random Number Generation

The method of verification for the random number generation must be described unless the supplied DBGEN and QGEN were used.

The TPC source based DBGEN and QGEN version 3.0.0 was used to generate all database populations.

2.3 Substitution Parameters Generation

The method used to generate values for substitution parameters must be disclosed. If QGEN is not used for this purpose, then the source code of any non-commercial tool used must be disclosed. If QGEN is used, the version number, release number, modification number and patch level of QGEN must be disclosed.

The TPC source based QGEN version 3.0.0 was used to generate the substitution parameters.

2.4 Query Text and Output Data from Database

The executable query text used for query validation must be disclosed along with the corresponding output data generated during the execution of the query text against the qualification database. If minor modifications (see Clause 2.2.3) have been applied to any functional query definitions or approved variants in order to obtain executable query text, these modifications must be disclosed and justified. The justification for a particular minor query modification can apply collectively to all queries for which it has been used. The output data for the power and throughput tests must be made available electronically upon request.

The Supporting Files Archive contains the query text and query output. The following modifications were used:

- The “dateadd” function is used to perform date arithmetic in Q1, Q4, Q5, Q6, Q10, Q12, Q14, Q15, and Q20.
- The “datepart” function is used to extract part of a date (“YY”) in Q7, Q8, and Q9.
- The “top” function is used to restrict the number of output rows in Q2, Q3, Q10, Q18, and Q21.
- The “count_big” function is used in place of “count” in Q1.

All the query substitution parameters used during the performance test must be disclosed in tabular format, along with the seeds used to generate these parameters.

The Supporting Files Archive contains the seed and query substitution parameters used.

2.6 Isolation Level

The isolation level used to run the queries must be disclosed. If the isolation level does not map closely to one of the isolation levels defined in Clause 3.4, additional descriptive detail must be provided.

The queries and transactions were run with isolation level “Read-Committed”.

All the query substitution parameters used during the performance test must be disclosed in tabular format, along with the seeds used to generate these parameters.

The Supporting Files Archive contains the seed and query substitution parameters used.
2.7 Refresh Functions

The details of how the refresh functions were implemented must be disclosed.

The Supporting Files Archive contains the source code for the refresh functions.
Clause 3: Database System Properties

3.1 ACID Properties

The ACID (Atomicity, Consistency, Isolation, and Durability) properties of transaction processing systems must be supported by the system under test during the timed portion of this benchmark. Since TPC-H is not a transaction processing benchmark, the ACID properties must be evaluated outside the timed portion of the test.

All ACID tests were conducted according to specification. The Supporting Files Archive contains the source code of the ACID test scripts.

3.2 Atomicity Requirements

The system under test must guarantee that transactions are atomic; the system will either perform all individual operations on the data, or will assure that no partially-completed operations leave any effects on the data.

3.2.1 Atomicity of Completed Transactions

Perform the ACID Transaction for a randomly selected set of input data and verify that the appropriate rows have been changed in the ORDERS, LINEITEM, and HISTORY tables.

The following steps were performed to verify the atomicity of the completed ACID transactions:

1. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for a randomly selected order key.
2. The ACID Transaction was performed using the order key from step 1.
3. The ACID Transaction was COMMITTED.
4. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for the same order key. It was verified that the appropriate rows had been changed.

3.2.2 Atomicity of Aborted Transactions

Perform the ACID Transaction for a randomly selected set of input data, substituting a ROLLBACK of the transaction for the COMMIT of the transaction. Verify that the appropriate rows have not been changed in the ORDERS, LINEITEM, and HISTORY tables.

The following steps were performed to verify the atomicity of the aborted ACID transactions:

1. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for a randomly selected order key.
2. The ACID Transaction was performed using the order key from step 1. The transaction was stopped prior to the commit.
3. The ACID Transaction was ROLLED BACK.
4. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for the same order key. It was verified that the appropriate rows had not been changed.

3.3 Consistency Requirements

Consistency is the property of the application that requires any execution of transactions to take the database from one consistent state to another. A consistent state for the TPC-H database is defined to exist when:

\[ O_{\text{TOTALPRICE}} = \text{SUM} (\text{trunc} (\text{trunc} ((L_{\text{EXTENDEDPRICE}} - L_{\text{DISCOUNT}}) \times (1 + L_{\text{TAX}}))) ) \]

for each ORDERS and LINEITEM defined by \( (O_{\text{ORDERKEY}} = L_{\text{ORDERKEY}}) \)
3.3.1 Consistency Test

Verify that ORDERS and LINEITEM tables are initially consistent as defined in Clause 3.3.2.1, based upon a random sample of at least 10 distinct values of O_ORDERKEY.

The following steps were performed to verify consistency:

1. The consistency of the ORDERS and LINEITEM tables was verified based on a sample of O_ORDERKEYs.
2. At least 100 ACID Transactions were submitted.
3. The consistency of the ORDERS and LINEITEM tables was re-verified.

The Consistency test was performed as part of the Durability test explained in Section 3.5:

3.4 Isolation Requirements

Operations of concurrent transactions must yield results which are indistinguishable from the results which would be obtained by forcing each transaction to be serially executed to completion in the same order.

3.4.1 Isolation Test 1 - Read-Write Conflict with Commit

Demonstrate isolation for the read-write conflict of a read-write transaction and a read-only transaction when the read-write transaction is committed.

The following steps were performed to satisfy the test of isolation for a read-only and a read-write committed transaction:

1. An ACID Transaction was started for a randomly selected O_KEY, L_KEY, and DELTA. The ACID Transaction was suspended prior to COMMIT.
2. An ACID Query was started for the same O_KEY used in step 1. The ACID query blocked and did not see any uncommitted changes made by the ACID Transaction.
3. The ACID Transaction was resumed and COMMITTED. The ACID query completed. It returned the data as committed by the ACID Transaction.

3.4.2 Isolation Test 2 - Read-Write Conflict with Rollback

Demonstrate isolation for the read-write conflict of a read-write transaction and a read-only transaction when the read-write transaction is rolled back.

The following steps were performed to satisfy the test of isolation for a read-only and a roll-backed read-write transaction:

1. An ACID Transaction was started for a randomly selected O_KEY, L_KEY, and DELTA. The ACID Transaction was suspended prior to ROLLBACK.
2. An ACID Query was started for the same O_KEY used in step 1. The ACID Query blocked and did not see the uncommitted changes made by the ACID Transaction.
3. The ACID Transaction was ROLLED BACK. The ACID Query completed.

3.4.3 Isolation Test 3 - Write-Write Conflict with Commit

Demonstrate isolation for the write-write conflict of two update transactions when the first transaction is committed.

The following steps were performed to verify isolation of two update transactions:

1. An ACID Transaction, T1, was started for a randomly selected O_KEY, L_KEY, and DELTA1. T1 was suspended prior to COMMIT.
2. Another ACID Transaction, T2, was started using the same O_KEY and L_KEY and a randomly selected DELTA2.
3. T2 was blocked by T1 and T2 waited.
4. The ACID Transaction T1 was allowed to COMMIT and T2 completed.
5. It was verified that: \[ T2.L_{EXTENDEDPRICE} = T1.L_{EXTENDEDPRICE} + (\text{DELTA1} \times (T1.L_{EXTENDEDPRICE} / T1.L_{QUANTITY})) \]

3.4.4 Isolation Test 4 - Write-Write Conflict with Rollback

Demonstrate isolation for the write-write conflict of two update transactions when the first transaction is rolled back.

The following steps were performed to verify isolation of two update transactions after the first one is rolled back:

1. An ACID Transaction, T1, was started for a randomly selected O_KEY, L_KEY, and DELTA1. T1 was suspended prior to ROLLBACK.
2. Another ACID Transaction, T2, was started using the same O_KEY and L_KEY and a randomly selected DELTA2.
3. T2 was blocked by T1. T2 waited.
4. T1 was allowed to ROLLBACK and T2 completed.
5. It was verified that T2.L_{EXTENDEDPRICE} = T1.L_{EXTENDEDPRICE}.

3.4.5 Isolation Test 5 - Concurrent Read and Write Transactions on Different Tables

Demonstrate the ability of read and write transactions affecting different database tables to make progress concurrently.

The following steps were performed to verify isolation of concurrent read and write transactions on different tables:

1. An ACID Transaction, T1, was started for a randomly selected O_KEY, L_KEY, and DELTA. The ACID Transaction, T1, was suspended prior to COMMIT.
2. Another ACID Transaction, T2, was started using random values of PS_PARTKEY and PS_SUPPKEY.
3. T2 completed.
4. T1 was allowed to COMMIT.
5. It was verified that appropriate rows in ORDERS, LINEITEM and HISTORY tables were changed.

3.4.6 Isolation Test 6 – Update Transaction during Continuous Read-Only Query Stream

Demonstrate that the continuous submission of arbitrary (read-only) queries against one or more tables of the database does not indefinitely delay update transactions affecting those tables from making progress.

The following steps were performed to verify isolation of update transactions during continuous read-only query:

1. An ACID Transaction, T1, executing a modified Q1 against the qualification database, was started. The substitution parameter was chosen from the interval \([0\ldots2159]\) so that the query ran for a sufficient amount of time.
2. Before T1 completed, an ACID Transaction, T2, was started for a randomly selected O_KEY, L_KEY and DELTA.
3. T2 completed before T1 completed
4. Transaction T1 completed executing the query Q1.
5. It was verified that appropriate rows in ORDERS, LINEITEM and HISTORY tables were changed

3.5 Durability Requirements

The system under test must guarantee durability: the ability to preserve the effects of committed transactions and insure database consistency after recovery from any one of the failures listed in Clause 3.5.3.3

3.5.1 System Crash / Memory Failure / Loss of External Power

System Crash: Guarantee the database and committed updates are preserved across an instantaneous interruption (system crash/system hang) in processing which requires the system to reboot to recover.

Memory Failure: Guarantee the database and committed updates are preserved across failure of all or part of memory (loss of contents).

Loss of External Power: Guarantee the database and committed updates are preserved during the loss of all external power for an indefinite time period

The durability of the system crash, memory failure, and loss of external power was tested together by the following steps:

1. The Consistency of the ORDERS and LINEITEM tables were verified.
2. Nine streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
3. While the streams of ACID transactions were running the System was powered off by pulling power plugs.
4. The power was restored the system booted.
5. Started the Virtual Machine and the SQL Database engine.
6. The database went through a recovery period. Rolled-forward, Rolled-backward transactions captured by the DB ERRORLOG file.
7. Recovery complete. The counts in the history table and success files were compared and verified, and the consistency of the ORDERS and LINEITEM tables was verified.

3.5.2 Failure of a Durable Medium

Guarantee the database and committed updates are preserved across a permanent irrecoverable failure of any single durable medium containing TPC-H database tables or recovery log tables.

The durability of the log and data disk failure was tested together by the following steps: (Note that the storage devices containing the TPC-H logs are mirrored across two pairs of SSDs, and the storage devices containing TPC-H tables and indexes are not mirrored.)

1. The complete database was backed up.
2. The Consistency of the ORDERS and LINEITEM tables were verified.
3. Nine streams of ACID transactions were started, with each stream executed a minimum of 100 transactions.
4. While the test was running, one of the RAID-10 configured log disks was removed.
5. It was determined that the test continued running, and the SQL Server did not generate an error.
6. While the test was running, one of the data disks (non-RAID) was removed.

7. The nine streams of ACID transactions failed and recorded the number of committed transactions in success files.

8. Stopped the SQL server.

9. Started the SQL server was with -f and -m option.

10. Backed up the database log and the database was dropped.

11. Stopped the SQL Server, and stopped the Virtual Machine.

12. The pulled disk was replaced with a new one.

13. Formatted the drive, and a new volume was created with same letter and file structure.


15. Restore the database.

16. When the database restore completed, a command was issued to apply the backed-up log file.

17. The counts in the history table and success files were compared and verified, and the consistency of the ORDERS and LINEITEM tables was verified.
Clause 4: Scaling and Database Population

4.1 Initial Cardinality of Tables

The cardinality (i.e., the number of rows) of each table of the test database, as it existed at the completion of the database load (see clause 4.2.5) must be disclosed.

The row count for each database table is shown in Table 4.1.

<table>
<thead>
<tr>
<th>Table</th>
<th># of Rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lineitem</td>
<td>18,000,048,306</td>
</tr>
<tr>
<td>Orders</td>
<td>4,500,000,000</td>
</tr>
<tr>
<td>Partsupp</td>
<td>2,400,000,000</td>
</tr>
<tr>
<td>Part</td>
<td>600,000,000</td>
</tr>
<tr>
<td>Customer</td>
<td>450,000,000</td>
</tr>
<tr>
<td>Supplier</td>
<td>30,000,000</td>
</tr>
<tr>
<td>Nation</td>
<td>25</td>
</tr>
<tr>
<td>Region</td>
<td>5</td>
</tr>
</tbody>
</table>

4.2 Distribution of Tables and Logs Across Media

The distribution of tables and logs across all media must be explicitly described for the tested and priced systems.

The database server on the Virtual Machine contains seven 3.84TB SAS SSDs and three 4TB NVMe SSDs. One SAS SSD is used to install the OS and DBMS, and the four others are configured as a RAID 10 to store the DBMS log. The remaining two SAS SSDs are configured as a RAID 0 volumes to store backups. The three NVMe SSDs are configured to store Test DB table data and temporary database (TempDB). Table 4.2 below shows the configuration of the database server.

<table>
<thead>
<tr>
<th># of Disks</th>
<th>Drive Description</th>
<th>RAID Format</th>
<th>Size (GB)</th>
<th>Driver Letter</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.84TB SSD SAS 12Gbps</td>
<td>No RAID</td>
<td>3,840</td>
<td>/var/opt/mssql</td>
<td>OS, SQL, DB root</td>
</tr>
<tr>
<td>1</td>
<td>4TB NVMe SSD</td>
<td>No RAID</td>
<td>4,000</td>
<td>/opt/db/data1</td>
<td>DB &amp; TempDB</td>
</tr>
<tr>
<td>1</td>
<td>4TB NVMe SSD</td>
<td>No RAID</td>
<td>4,000</td>
<td>/opt/db/data2</td>
<td>DB &amp; TempDB</td>
</tr>
<tr>
<td>1</td>
<td>4TB NVMe SSD</td>
<td>No RAID</td>
<td>4,000</td>
<td>/opt/db/data3</td>
<td>DB &amp; TempDB</td>
</tr>
<tr>
<td>4</td>
<td>3.84TB SSD SAS 12Gbps</td>
<td>RAID 10</td>
<td>3,840</td>
<td>/opt/db/log</td>
<td>DB Log</td>
</tr>
<tr>
<td>2</td>
<td>3.84TB SSD SAS 12Gbps</td>
<td>RAID 0</td>
<td>3,840</td>
<td>/opt/db/backup</td>
<td>Backup</td>
</tr>
</tbody>
</table>
4.3 Database partition/replication mapping

The mapping of database partitions/replications must be explicitly described.

Horizontal partitioning is used on LINEITEM and ORDERS tables and the partitioning columns are L_SHIPDATE and O_ORDERDATE. The database partitions are evenly distributed across 3 NVMe drives.

4.4 Data redundancy mechanisms

Implementations may use data redundancy mechanism(s). The type of data redundancy mechanisms(s) and any configuration parameters, i.e., RAID level must be disclosed for each device.

The database tables were hosted on three 4TB NVMe drives. The temporary files were hosted on the same drives as the database tables. The database log files resided on a RAID-10 array of four 3.84TB SAS SSDs. The database backup was hosted on another RAID-0 array made of two 3.84TB SSDs.

4.5 Modifications to the DBGEN

The version number, release number, modification number, and patch level of DBGEN must be disclosed. Any modifications to the DBGEN (see Clause 4.2.1) source code must be disclosed. If a program other than DBGEN was used to populate the database, it must be disclosed in its entirety.

DBGEN version 3.0.0 was used, no modifications were made.

4.6 Database Load Time

The database load time for the test database (see clause 4.3) must be disclosed.

The database load time was 00d 08h 30m 35s.

<table>
<thead>
<tr>
<th>Load Test Times</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Start</td>
<td>2023-12-07 09:37:55</td>
</tr>
<tr>
<td>Load End</td>
<td>2023-12-07 18:08:28</td>
</tr>
<tr>
<td>Load Delay</td>
<td>00d 00h 00m 00s</td>
</tr>
<tr>
<td>Load Time</td>
<td>00d 08h 30m 33s</td>
</tr>
</tbody>
</table>

4.7 Data Storage Ratio

The data storage ratio must be disclosed. It is computed by dividing the total data storage of the priced configuration (expressed in GB) by the size chosen for the test database as defined in 4.1.3.1. The ratio must be reported to the nearest 1/100th, rounded up. For the reporting of configured disk capacity, gigabyte (GB) is defined to be 2^30 bytes.

The computation of the data storage ratio is shown in Table 4.3 and 4.4.

<table>
<thead>
<tr>
<th>Disk Type</th>
<th>GB per Disk*</th>
<th># of disks</th>
<th>Total Space (GB)</th>
<th>Total Space (GiB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAS SSD</td>
<td>3,840 GB</td>
<td>7</td>
<td>26,880</td>
<td>25,033.95</td>
</tr>
<tr>
<td>NVMe SSD</td>
<td>4,000 GB</td>
<td>7</td>
<td>28,000</td>
<td>26,077.03</td>
</tr>
<tr>
<td>Total Storage</td>
<td>51,110.98</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Storage Ratio</td>
<td></td>
<td></td>
<td></td>
<td>17.04</td>
</tr>
</tbody>
</table>
Table 4.4: Data Storage Ratio Computation of Virtual Server

<table>
<thead>
<tr>
<th>Disk Type</th>
<th>GB per Disk*</th>
<th># of disks</th>
<th>Total Space (GB)</th>
<th>Total Space (GiB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAS SSD</td>
<td>3,840 GB</td>
<td>7</td>
<td>26,880</td>
<td>25,033.96</td>
</tr>
<tr>
<td>NVMe SSD</td>
<td>4,000 GB</td>
<td>3</td>
<td>12,000</td>
<td>11,175.87</td>
</tr>
<tr>
<td>Total Storage</td>
<td></td>
<td></td>
<td>36,209.83</td>
<td></td>
</tr>
<tr>
<td>Data Storage Ratio</td>
<td></td>
<td></td>
<td>12.07</td>
<td></td>
</tr>
</tbody>
</table>

4.8 Database Load Mechanism Details and Illustration

The details of the database load must be reported in the supporting files archive. Disclosure of the load procedure includes all steps, scripts, input and configuration files required to completely reproduce the test and qualification databases. A block diagram illustrating the overall process must be disclosed.

The database was loaded using data generated by DBGEN and stored in flat files located on the OS partition of the system disk, as shown in Table 4.2.

The database load mechanism is depicted in Figure 4.5.

Figure 4.5: Block Diagram of Database Load Process
4.9 Qualification Database Configuration

*Any differences between the configuration of the qualification database and the test database must be disclosed.*

The qualification database used identical scripts to create and load the data with changes to adjust for the database scale factor.

4.10 Memory Ratio

*The memory to database size ratio must be disclosed.*

The computation of the percentage of memory to database size is shown in Table 4.6 and 4.7.

<table>
<thead>
<tr>
<th>Memory Size (GiB)</th>
<th>2,048</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale Factor (SF)</td>
<td>3,000</td>
</tr>
<tr>
<td>Percentage of Memory</td>
<td>68.3%</td>
</tr>
</tbody>
</table>

**Table 4.6: Percentage of Physical Memory Computation**

<table>
<thead>
<tr>
<th>Memory Size (GiB)</th>
<th>3,072</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale Factor (SF)</td>
<td>3,000</td>
</tr>
<tr>
<td>Percentage of Memory</td>
<td>102.4%</td>
</tr>
</tbody>
</table>

**Table 4.7: Percentage of Virtual Memory Computation**
Clause 5: Performance Metrics

5.1 System Activity Between Load and Performance Tests

Any system activity on the SUT that takes place between the conclusion of the load test and the beginning of the performance test must be fully disclosed including listings of scripts, command logs and system activity. There was no system activity on the SUT between the conclusion of the load and the beginning of the performance test.

5.2 Steps in the Power Test

The details of the steps followed to implement the power test (e.g., system boot, database restart, etc.) must be disclosed. The following steps were used to implement the power test:

1. RF1 Refresh Function by refresh stream
2. Stream 0 Execution by query stream
3. RF2 Refresh Function by refresh stream

5.3 Timing Intervals for Each Query and Refresh Functions

The timing intervals (see Clause 5.3.7) for each query and for both refresh functions must be reported for the power test. The timing intervals for each query and for both refresh functions are contained in the Numerical Quantities section of the Executive Summary at the beginning of this report.

5.4 Number of Streams for the Throughput Test

The number of execution streams used for the throughput test must be disclosed. 8 query streams were used for the throughput test.

5.5 Start and End Date/Times for Each Query Stream

The start time and finish time for each query stream for the throughput test must be disclosed. The throughput test start time and finish time for each stream are contained in the Numerical Quantities section of the Executive Summary at the beginning of this report.

5.6 Total Elapsed Time of the Measurement Interval

The total elapsed time of the measurement interval (see Clause 5.3.6) must be reported for the throughput test. The total elapsed time of the throughput test is contained in the Numerical Quantities section of Executive Summary at the beginning of this report.

5.7 Refresh Function Start Date/Time and Finish Date/Time

The start time and, finish time for each refresh function in the refresh stream for the throughput test must be disclosed. The start and finish times for each refresh function in the refresh stream are contained in the Numerical Quantities section of the Executive Summary at the beginning of this report.
5.8 Timing Intervals for Each Query and Each Refresh Function for Each Stream

The timing intervals (see Clause 5.3.6) for each query of each stream and for each update function must be reported for the throughput test.

The timing intervals for each query and each refresh function for each stream are contained in the Numerical Quantities section of the Executive Summary at the beginning of this report.

5.9 Performance Metrics

The computed performance metric, related numerical quantities and price performance metric must be reported.

The performance metrics, and the numbers on which they are based, are contained in the Numerical Quantities section of the Executive Summary at the beginning of this report.

5.10 The Performance Metric and Numerical Quantities from Both Runs

A description of the method used to determine the reproducibility of the measurement results must be reported. This must include the performance metrics (QppH and QthH) from the reproducibility runs.

Performance results from the first two executions of the TPC-H benchmark is shown in Table 5.1.

<table>
<thead>
<tr>
<th>Run ID</th>
<th>QppH@3000GB</th>
<th>QthH@3000GB</th>
<th>QphH@3000GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run1</td>
<td>312,243.4</td>
<td>105,442.4</td>
<td>181,448.9</td>
</tr>
<tr>
<td>Run2</td>
<td>328,986.5</td>
<td>111,157.8</td>
<td>191,231.3</td>
</tr>
</tbody>
</table>

5.11 System Activity Between Performance Tests

Any activity on the SUT that takes place between the conclusion of Run1 and the beginning of Run2 must be fully disclosed including system activity, listings of scripts or command logs along with any system reboots or database restarts.

There was no activity on the SUT between Run1 and Run 2.

5.12 Documentation to satisfy Clause 5.2.7

All documentation necessary to satisfy Clause 5.2.7 must be made available upon request.

The Supporting Files Archive contains the documentation.

5.13 Query Output Validation

The output of the Query Output Validation Test must reported in the supporting files archive.

The Supporting Files Archive contains the output of the query validation test.
Clause 6: SUT and Driver Implementation

6.1 Driver

A detailed description of how the driver performs its functions must be supplied, including any related source code or scripts. This description should allow an independent reconstruction of the driver.

The TPC-H benchmark was implemented using a Microsoft tool called StepMaster. StepMaster is a general-purpose test tool which can drive ODBC and shell commands. Within StepMaster, the user designs a workspace corresponding to the sequence of operations (or steps) to be executed. When the workspace is executed, StepMaster records information about the run into a database as well as a log file for later analysis.

StepMaster provides a mechanism for creating parallel streams of execution. This is used in the throughput tests to drive the query and refresh streams. Each step is timed using a millisecond resolution timer. A timestamp T1 is taken before beginning the operation and a timestamp T2 is taken after completing the operation. These times are recorded in a database as well as a log file for later analysis.

Two types of ODBC connections are supported. A dynamic connection is used to execute a single operation and is closed when the operation finishes. A static connection is held open until the run completes and may be used to execute more than one step. A connection (either static or dynamic) can only have one outstanding operation at any time.

In TPC-H, static connections are used for the query streams in the power and throughput tests. StepMaster reads an Access database to determine the sequence of steps to execute. These commands are represented as the Implementation Specific Layer. StepMaster records its execution history, including all timings, in the Access database. Additionally, StepMaster writes a textual log file of execution for each run.

The stream refresh functions were executed using multiple batch scripts. The initial script is invoked by StepMaster, subsequent scripts are called from within the scripts.

The source for StepMaster and the RF Scripts is disclosed in the supported file archive.

6.2 Implementation Specific Layer(ISL)

If an implementation specific layer is used, then a detailed description of how it performs its functions must be supplied, including any related source code or scripts. This description should allow an independent reconstruction of the implementation-specific layer.

See Section 6.1 for details

6.3 Profile-Directed Optimization

If profile-directed optimization as described in Clause 5.2.9 is used, such use must be disclosed.

Profile-directed optimization was not used.
Clause 7: Pricing

7.1 Hardware and Software Used

A detailed list of hardware and software used in the priced system must be reported. Each item must have a vendor part number, description, and release/revision level, and indicate general availability status or committed delivery date. If package-pricing is used, contents of the package must be disclosed. Pricing source(s) and effective date(s) of price(s) must be reported.

A detailed list of all hardware and software used in the priced system is in the Executive Summary section at the beginning of this report. The price quotations are included in the APPENDIX A.

7.2 Three-Year Cost of System Configuration

The total 3-year price of the entire configuration must be reported, including: hardware, software, and maintenance charges. Separate component pricing is required.

A detailed list of all hardware and software, including 3-year maintenance and applicable discounts, is in the Executive Summary section at the beginning of this report. The price quotations are included in the APPENDIX A.

7.3 Availability Dates

The committed delivery date for general availability (availability date) of products used in the price calculations must be reported. When the priced system includes the product with different availability, the single availability date reported on the first page of the Executive Summary must be the date by which all components are committed to being available. The full disclosure report must report availability dates individually for at least each of the categories for which a pricing subtotal must be provided.

The total system is available now.
Clause 8: Supporting Files Index Table

An index for all files included in the supporting files archive as required by Clause 8.3.2 through 8.3.8 must be provided in the report.

Table 8.1: File list per each Clause

<table>
<thead>
<tr>
<th>Clause</th>
<th>Description</th>
<th>Archive File</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clause 1</td>
<td>OS and DB parameter settings</td>
<td>SupportingFilesArchive\Clause1</td>
</tr>
<tr>
<td>Clause 2</td>
<td>DB creation scripts</td>
<td>SupportingFilesArchive\Clause2</td>
</tr>
<tr>
<td>Clause 3</td>
<td>ACID scripts, ACID output</td>
<td>SupportingFilesArchive\Clause3</td>
</tr>
<tr>
<td>Clause 4</td>
<td>DB Load scripts, Qualification output</td>
<td>SupportingFilesArchive\Clause4</td>
</tr>
<tr>
<td>Clause 5</td>
<td>Query output results</td>
<td>SupportingFilesArchive\Clause5</td>
</tr>
<tr>
<td>Clause 6</td>
<td>Implementation Specific layer source code</td>
<td>SupportingFilesArchive\Clause6</td>
</tr>
<tr>
<td>Clause 7</td>
<td>There are no files to be included for Clause 7</td>
<td>SupportingFilesArchive\Clause7</td>
</tr>
<tr>
<td>Clause 8</td>
<td>Query substitution parameters, RF function source</td>
<td>SupportingFilesArchive\Clause8</td>
</tr>
</tbody>
</table>
Clause 9: Auditor Attestation

9.1 Auditor Information

The auditor’s agency name, address, phone number, and Attestation letter with a brief audit summary report indicating compliance must be included in the full disclosure report. A statement should be included specifying who to contact in order to obtain further information regarding the audit process.

This benchmark was audited by:

InfoSizing
Doug Johnson
63 Lourdes Drive
Leominster, MA 01453-6709
Phone: +1 (978) 343-6262
www.sizing.com

9.2 Attestation Letter

The auditor’s attestation letter is included in the following pages.
Attestation Letter

Benchmark sponsor: Hyo-Sil Kim
Telecommunications Technology Association
47, Bundang ro, Bundang gu, Seongnam-city
Gyeonggi-do, 13591, Republic of Korea

January 31, 2024

I verified the TPC Benchmark H (TPC-H™ v3.0.1) performance of the following configuration:

- **Platform:** SYSGEAR M50CYP2UR208_6334
- **Operating System:** Red Hat Enterprise Linux 7.3
- **Database Manager:** Microsoft SQL Server 2019 Enterprise Edition
- **Other Software:** SEMS (Software Defined Memory Solution)

The results were:

- **Performance Metric**: 1,488.9 QphH@3.000GB
- **TPC-H Power**: 312,243.4
- **TPC-H Throughput**: 105,442.4
- **Database Load Time**: 00d 08h 30m 33s

<table>
<thead>
<tr>
<th>Server</th>
<th>SYSGEAR M50CYP2UR208_6334, with:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU(s)</td>
<td>2x Intel® Xeon® gold 6334 (3.6 GHz, 8-Core, 18 MB Cache)</td>
</tr>
<tr>
<td>Memory</td>
<td>2,048 GB</td>
</tr>
<tr>
<td>Disks</td>
<td>Qty Size Type</td>
</tr>
<tr>
<td></td>
<td>7 3.84 TB SAS SSD</td>
</tr>
<tr>
<td></td>
<td>7 4 TB NVMe</td>
</tr>
</tbody>
</table>

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:
- The database records were defined with the proper layout and size.
- The database population was generated using DBGen.
- The database was properly scaled to 3,000GB and populated accordingly.
- The compliance of the database auxiliary data structures was verified.
- The database load time was correctly measured and reported.
- The required ACID properties were verified and met.

63 Lourdes Dr. | Leominster, MA 01453 | 978-343-6562 | www.sizing.com
The query input variables were generated by QGen.
The query text was produced using minor modifications and no query variant.
The execution of the queries against the SF1 database produced compliant answers.
A compliant implementation specific layer was used to drive the tests.
The throughput tests involved 8 query streams.
The ratio between the longest and the shortest query was such that no query timings were adjusted.
The execution times for queries and refresh functions were correctly measured and reported.
The repeatability of the measured results was verified.
The system pricing was verified for major components and maintenance.
The major pages from the FDR were verified for accuracy.

Additional Audit Notes:
None.

Respectfully Yours,

Doug Johnson, TPC Certified Auditor
APPENDIX A: Price Quotations

Server (SYSGEAR M50CYP2UR208 6334 Hardware and 3-Year Maintenance)
# 1 Price Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit Price</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS03TP2U0208_6834</td>
<td>153,120.90</td>
<td>153,120.90</td>
</tr>
<tr>
<td>Discount</td>
<td>6,156.44</td>
<td>-6,156.44</td>
</tr>
</tbody>
</table>

**Subtotal**

W 146,962,460

**VAT : 10%**

W 14,696,246

**Total**

W 161,658,706

<table>
<thead>
<tr>
<th>Code No.</th>
<th>Customer No.</th>
<th>Payment Terms</th>
<th>End User Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Billing Address:****

**Shipment Address:**

**Customer PO Number:**

**Customer Signature:**

번 품성의 무심 보증기간은 1년, 유상 2년 입니다.
재품 보증기간 경과 후 발생하는 고정에 대해서는 유상으로 플러그들이 라.
본 품성은 전자파 적합성 평가를 받은 구분용으로 제작되었으며, 양성품에 대해서는 평가를 받지 않은 품성입니다.
본 품성은 경제적인 후 재작 및 반송되지 않으시면, 경제적인 무상으로 배송됩니다.

**사기어 결제정보**

* 협력업체 이해주 개발정보를 참고하여 주시기 바랍니다.*

<table>
<thead>
<tr>
<th>대표전화</th>
<th>1522 9888</th>
</tr>
</thead>
<tbody>
<tr>
<td>대표전화</td>
<td>1522 9888</td>
</tr>
</tbody>
</table>
## 2 Quote Details

**M50CYP2UR20B_6334**

<table>
<thead>
<tr>
<th>QTY</th>
<th>Unit Price</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>158,120,800</td>
<td>158,120,800</td>
</tr>
</tbody>
</table>

### Components

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
<th>Extended Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intel® Server System M50CYP2UR20B, 2U</td>
<td>2,100,000</td>
</tr>
<tr>
<td>2</td>
<td>Intel® Xeon® Gold 6334 Processor (8-Core 3.00GHz/18MB)</td>
<td>9,000,000</td>
</tr>
<tr>
<td>32</td>
<td>(Seagate) Nitro XS3840SE2T/124 3.8TB</td>
<td>7,000,000</td>
</tr>
<tr>
<td>7</td>
<td>(Seagate) FireCuda 500 2TB 4000GB/4000 3.4TB</td>
<td>2,050,000</td>
</tr>
<tr>
<td>2</td>
<td>Quid M.2 Mobile PCIe 4.0 x4 PCIe x16</td>
<td>320,000</td>
</tr>
<tr>
<td>1</td>
<td>Intel® Ethernet Network Adapter X710-1TL for OCP 3.0</td>
<td>390,000</td>
</tr>
<tr>
<td>2</td>
<td>120W Power Supply</td>
<td>500,000</td>
</tr>
<tr>
<td>1</td>
<td>2U Riser #1 w/1 Elite DW slot</td>
<td>110,000</td>
</tr>
<tr>
<td>1</td>
<td>2U Riser #2 w/18-OW cable</td>
<td>110,000</td>
</tr>
<tr>
<td>1</td>
<td>2U 2 slots Riser #3</td>
<td>110,000</td>
</tr>
<tr>
<td>1</td>
<td>Cable kit for 2U BB to 6 x 2.5” drives if 6 drives</td>
<td>110,000</td>
</tr>
<tr>
<td>1</td>
<td>Intel® Cabled kit CYP62H3HC2X1, Single</td>
<td>65,000</td>
</tr>
<tr>
<td>1</td>
<td>2L GRGPU Kit (Includes airducts, bracket, power cables)</td>
<td>100,000</td>
</tr>
<tr>
<td>1</td>
<td>2U Bezel</td>
<td>55,000</td>
</tr>
<tr>
<td>1</td>
<td>Half extension rail kit</td>
<td>55,000</td>
</tr>
<tr>
<td>2</td>
<td>Heat Sink tal 1U or 2U capable</td>
<td>170,000</td>
</tr>
<tr>
<td>1</td>
<td>Intel® PAC Adapter P530CDU</td>
<td>430,000</td>
</tr>
<tr>
<td>1</td>
<td>24 - Inch Monitor</td>
<td>150,000</td>
</tr>
<tr>
<td>1</td>
<td>Mouse</td>
<td>26,000</td>
</tr>
</tbody>
</table>

### Software

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
<th>Extended Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SQL Server 2019 Enterprise – 2 Core License Pack</td>
<td>110,292,000</td>
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<td>1</td>
<td>Microsoft Problem Resolution Services (3Y, 7x24x4)</td>
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<td>EMED 10(3Y, 5x24x4)</td>
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### Service

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<th>Extended Price</th>
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<td>M50CYP2UR20B_6334_3-Yr. main(1x24x4)</td>
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Linux OS (Red Hat Enterprise Linux Operation System Platform)

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<th>Description</th>
<th>Unit</th>
<th>客관금액</th>
<th>소비자금</th>
<th>공급단가</th>
<th>공급금계</th>
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<tr>
<td>OS</td>
<td>Red Hat Enterprise Linux Operating System Platform</td>
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<td>RHE0004</td>
<td>Red Hat Enterprise Linux Server, Standard (Physical or Virtual Nodes) 3Year support</td>
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<td>Maintenance</td>
<td>Rockplace Support Carepack - Linux Premium 3Year</td>
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<td>RP-CPS(OS)</td>
<td>3 Year, 24x7 hr. response</td>
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소계 금액: 3,453,000

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<th>Remarks</th>
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| 1. 연간 Subscription 식별이며, 기간이 만료된 경우 Renewal을 출처하지 않습니다. (중요 유지수수료 100%)
| 2. 필요 시에는 판매자 고객 지원(문의처)에 담당자, 연락처, Email이 알려져 있습니다.
| 3. 원하시는 기술지원 lvl 기술지원의 필요성과 관련되는 '제목'을 구매하시십시오.